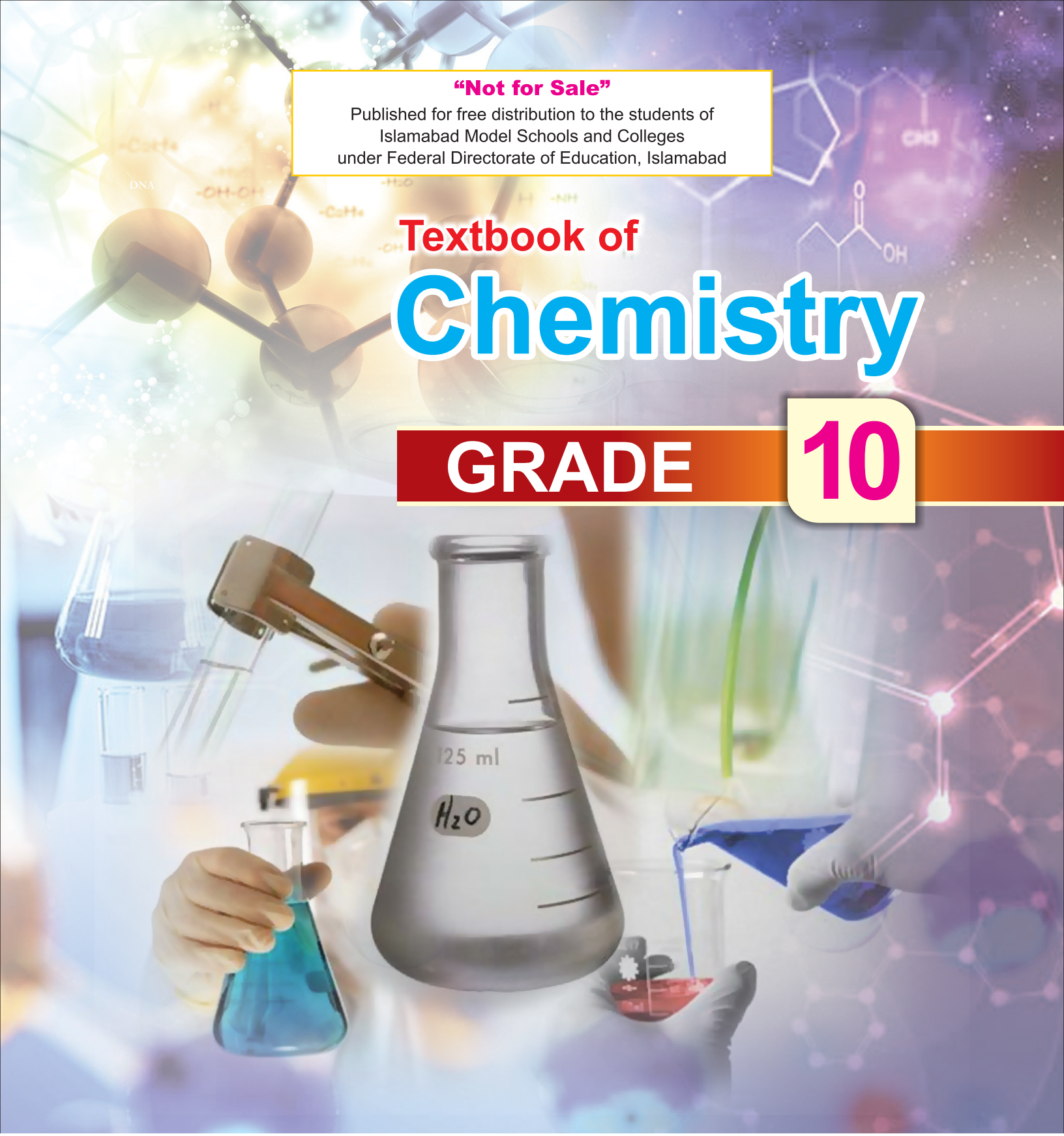

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Textbook of Chemistry

GRADE 10

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Textbook of

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OUR MOTTO

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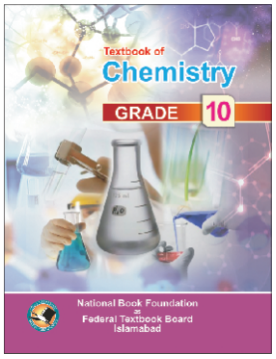
Textbook of
Chemistry Grade - 10



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PREFACE

Textbook of **Chemistry Grade 10** is developed according to the National Curriculum 2006 and National Style Guide. It is being published since 2013 and now it is presented under the new management and supervision of textbook development principles and guidelines with new designing and layout.

Chemistry Grade 10 aims to bring themes and topics closer to the interests of the children. The activities are also intended to encourage them towards taking the responsibility of their own learning. The success of the book will depend upon the ownership of the children towards declaring the book as their favourite.

In the previous sessions the students have gone through a mind map of the chemistry division. Half of this divide was introduced there. Now they will go beyond the organic, bio and usage of chemistry in the industries and their effect on environment.

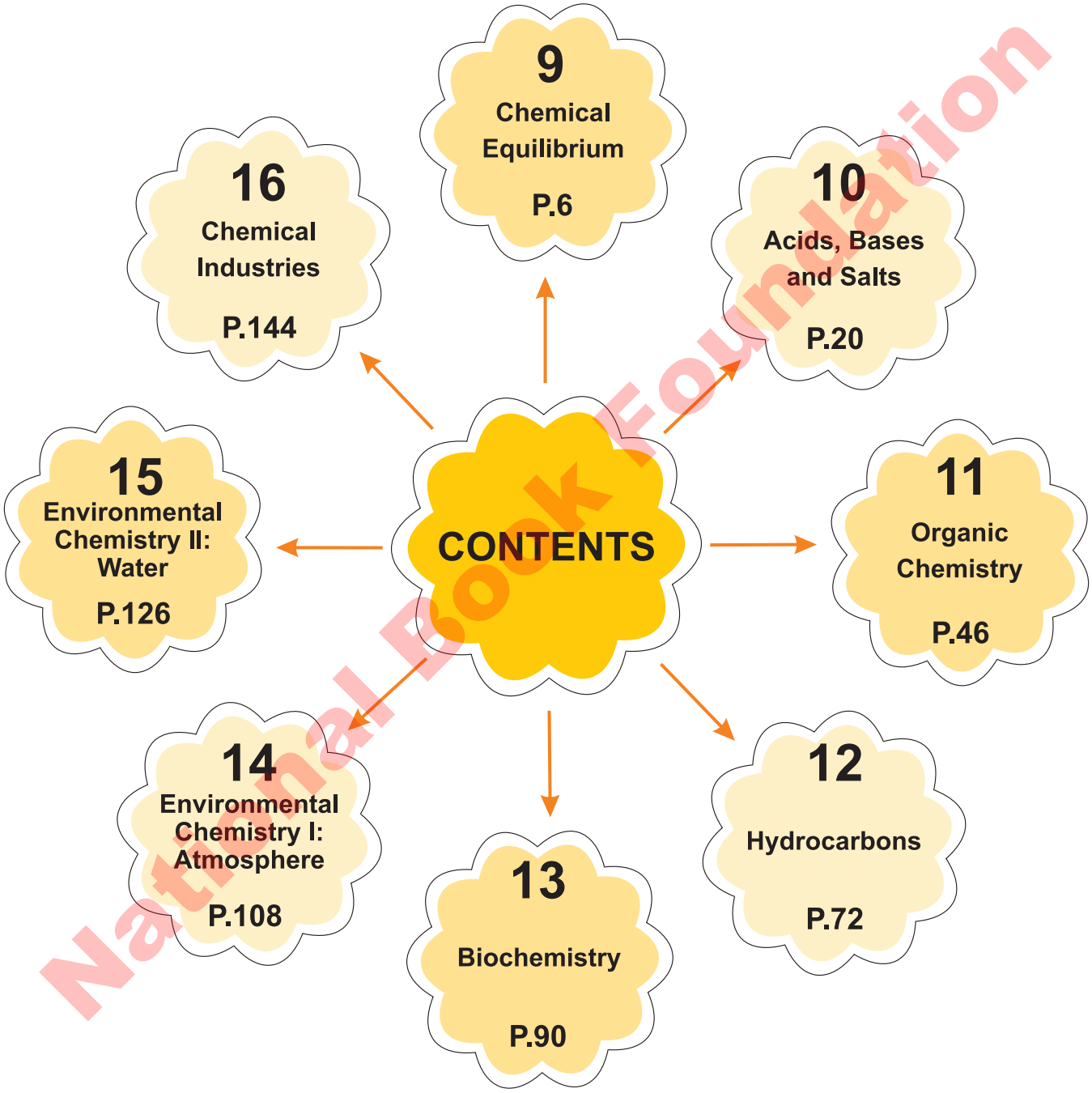
This book is now presented in a new way so that Chemistry should become a vital subject. The text items given in the exercises are for learning reinforcement. The examination questions are to be prepared according to the SLO's and the Bloom's Taxonomy.

Quality of Standards, Pedagogical Outcomes, Taxonomy Access and Actualization of Style is our motto. With these elaborations, this series of new development is presented for use. After educational feedback and necessary changes, the book is being published again.

National Book Foundation

بِسۡمِ اللّٰہِ الرَّحۡمٰنِ الرَّحِیۡمِ ؕ

اللہ کے نام سے شروع جو بڑا مہربان، نہایت رحم والا ہے



9

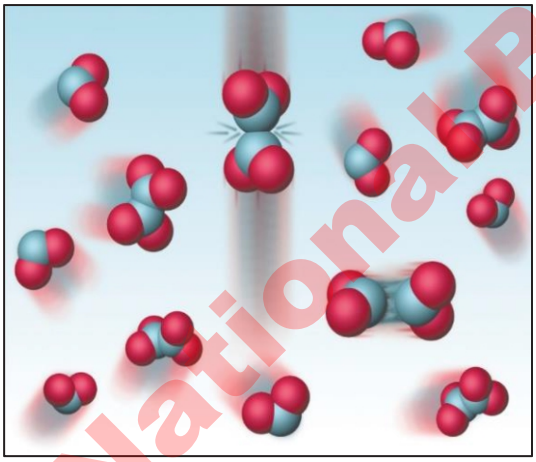
CHEMICAL EQULIBRIUM

After completing this lesson, you will be able to:

This is 11 days lesson (period including homework)

- Define chemical equilibrium in terms of a reversible reaction.
- Write both the forward and the reverse reactions and describe the macroscopic characteristics of each.
- Define Law of mass action
- Derive an expression for the equilibrium constant and its units
- State the necessary conditions for equilibrium and the ways that equilibrium can be recognized.
- Write the equilibrium constant expression of a reaction.
- Write the equilibrium constant expression for a given chemical reaction.
- Explain how components of atmosphere can be used successfully in producing important chemicals.

Reading



INTRODUCTION:

A complete reaction is one in which all the reactants have been converted to products. However, many important chemical reactions do not complete and a mixture of products and reactants are formed. In such a reaction product react together to re-form reactants. At the same time reactants form products. These reactions are called reversible reactions. An understanding of equilibrium is important in the chemical industry. Equilibrium reactions are involved in some of the stages in the commercia,l production of many important chemicals such as ammonia, sulphuric acid etc.

In a closed container, the formation of ammonia from its elements does not proceed to any great extent. Yet as you will learn in this chapter, this vital substance is manufactured on multimillion ton scale annually by applying the principles of equilibrium. How? You will learn many important things about chemical equilibrium in this chapter.

9.1 REVERSIBLE REACTIONS AND DYNAMIC EQUILIBRIUM.

Recall what happens when some liquid is placed in a closed container? You have learnt about it in grade IX.

Some of the liquid undergoes a physical change by evaporating. As more liquid evaporates, some of the vapours condense due to collision with the surface of the liquid. Eventually the rate of evaporation equals the rate of condensation. At this stage equilibrium is established between forward and reverse changes.

Liquid $\rightleftharpoons$ Vapours

Many chemical reactions do not reach completion. In such reactions the conversion of reactants into products and conversion of products into reactants can happen simultaneously. **A reaction in which the products can react together to re-form the original reactants is called reversible reaction OR a reaction which proceeds in the forward direction as well as in the reverse direction under the same conditions is called a reversible reaction. These reactions never go to completion.** All reversible changes (physical and chemical) occur simultaneously in both the directions. The double arrow ($\rightleftharpoons$) in the chemical equation shows that the reaction is reversible. For example:

$2SO_{2(g)}$	+	$O_{2(g)}$	$\overset{V_2O_5}{\rightleftharpoons}$	$2SO_{3(g)}$
Sulphur dioxide		Oxygen	**450°C, 200 atm**	Sulphur trioxide
$N_{2(g)}$	+	$3H_{2(g)}$	$\overset{Fe}{\rightleftharpoons}$	$2NO_{2(g)}$
Nitrogen		Hydrogen	**400°C, 200 atm**	Ammonia
$2N_{2(g)}$	+	$O_{2(g)}$	$\overset{Electric}{\rightleftharpoons}$	$2NO_{2(g)}$
Nitric oxide		Oxygen	**spark**	Nitrogen dioxide

Consider what happens when SO_2 and O_2 gases are mixed in a sealed container (Figure 9.1)

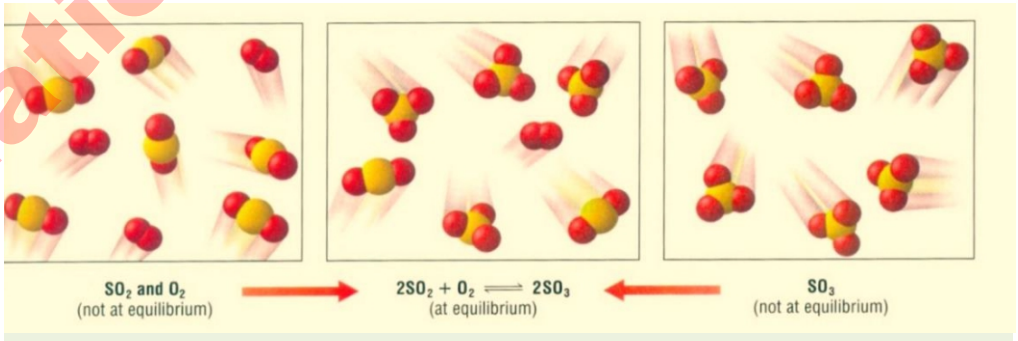


Figure 9.1 Reaction between SO_2 and O_2

Teacher's Point

Teacher may give more examples of reversible reactions.

Science Titbits

When fizzy drinks are made, CO_2 is dissolved in the liquid drink under pressure and sealed. When you remove lid of the bottle, bubbles of CO_2 suddenly appear. When you put the lid back on the bottle, the bubbles stop. This is due to the following equilibrium.

$$CO_{2(g)} \rightleftharpoons CO_{2(aq)}$$

The forward reaction happens during manufacturing and the reverse reaction happens on opening.

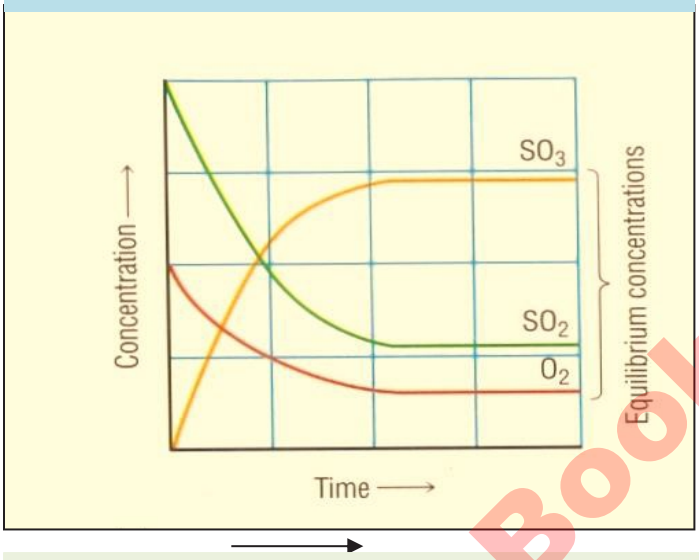


Figure 9.2 Concentration-time graph

Molecules of SO_2 and O_2 react to give SO_3. Molecules of SO_3 decompose to give SO_2 and O_2. What types of molecules are present at equilibrium?

In the first reaction (from left to right) SO_2 and O_2 produce SO_3. In the second reaction (from right to left) SO_3 decompose into SO_2 and O_2.

Which reaction is called forward reaction?

Which reaction is called the reverse reaction?

Initially there is no SO_3. So the rate of reverse reaction is zero. The rate of forward reaction is the highest, due to the high concentration of reactants. As the reaction proceeds, the concentration of reactants gradually decreases and the rate of forward reaction also decreases proportionately. (Figure 9.1)

$$2SO_{2(g)} + O_{2(g)} \longrightarrow SO_{3(g)}$$

As the concentration of SO_3 increases, a small amount of SO_3 slowly decomposes to SO_2 and O_2. This means reverse reaction has begun. In this reaction SO_3 acts as reactant and produces SO_2 and O_2. So the reverse reaction is

$$2SO_{3(g)} \longrightarrow 2SO_{2(g)} + O_{2(g)}$$

As the concentration of SO_3 becomes higher, the reverse reaction speeds up. Eventually the two rates become equal. At this stage SO_3 decomposes to SO_2 and O_2 as fast as SO_2 and O_2 produce SO_3. At this stage reaction is said to have reached equilibrium state. (Figure 9.2)

A state of a chemical reaction in which forward and reverse reactions take place at the same rate is called chemical equilibrium.

Chemical equilibrium is a dynamic equilibrium. This is because reactions do not stop when they come to equilibrium state. The individual molecules keep on reacting continuously. But

there is no change in the actual amounts of reactants and products. This means concentration of reactants and products become constant at equilibrium stage.

Example 9.1: Writing the forward and the reverse reactions

Write the forward and the reverse reactions for the following reversible reactions.

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2\,(g)}$$

Problem Solving Strategy:

1. The reaction from left to right is the forward reaction.
2. The reaction from right to left is the reverse reaction.

Solution:

Forward reaction

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2\,(g)}$$

Reverse reaction

$$2NO_{2(g)} \longrightarrow 2NO_{(g)} + O_{2(g)}$$

Self Assessment Exercise – 9.1

Write both forward and reverse reactions and describe macroscopic characteristics of each?

(i) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(ii) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

Reading

9.2. LAW OF MASS ACTION AND DERIVATION OF THE EXPRESSION FOR THE EQUILIBRIUM CONSTANT

Chemists generally express the composition of equilibrium mixture in terms of numerical values. These values relate the amounts of products to reactants at equilibrium. These values can be determined by using a relationship known as "**The law of mass action".**

Two chemists C.M Guldberg and P. Waage in 1864 proposed the law of mass action to describe the equilibrium state.

It states that the rate at which a substance reacts is directly proportional to its active mass. The rate at which the reaction proceeds, is directly proportional to the product of the active masses of the reactants.

The term "**active mass**" represents the concentration of reactants and products in mol.dm^{-3} for a dilute solution, and is expressed in terms of square brackets [ ].

Consider a hypothetical reaction in which 'a' moles of reactant A and 'b' moles of reactant B react to give 'c' moles of product C and 'd' moles of product D at equilibrium.

$$aA_{(g)} + bB_{(g)} \rightleftharpoons cC_{(g)} + dD_{(g)}$$

According to the law of mass action;

Rate of forward reaction $\propto [A]^a[B]^b$

Rate of forward reaction = $k_f[A]^a[B]^b$

Rate of reverse reaction $\propto [C]^c[D]^d$

Rate of reverse reaction= $k_r[C]^c[D]^d$

Where K_f and K_r are the rate constants for forward and the reverse reactions respectively

At equilibrium state:

Rate of forward reaction = Rate of reverse reaction

Thus

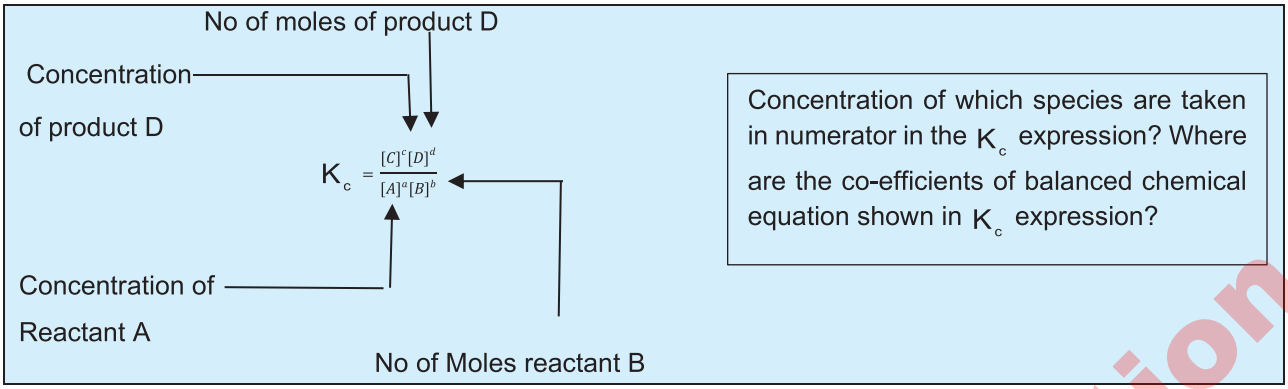
$$k_f\ [A]^a\ [B]^b = k_r\ [C]^c\ [D]^d$$

On rearranging $\frac{k_f}{k_r} = \frac{[C]^c\ [D]^d}{[A]^a\ [B]^b}$

$$K_c = \frac{[C]^c\ [D]^d}{[A]^a\ [B]^b}$$

Where $K_c = \frac{k_f}{k_r}$ and is known as equilibrium constant, and the above equation is called as equilibrium constant expression. The square brackets indicate the concentration of the chemical species at equilibrium in moles/dm^{-3}. Thus the equilibrium constant expression for any reaction can be written from its balanced equation. Concentration of products is taken in the numerator and concentration of reactants in the denominator. In K_c, the subscript 'c' denotes molar concentration at equilibrium.

Equilibrium constant is defined as the ratio of the product of concentration of products to the product of concentration of reactants each raised to the power equal to the coefficient in the balanced chemical equation. K_c is independent of the initial concentration of reactants but depends upon temperature.



Example 9.2: Writing Equilibrium Constant Expression.

Coal can be converted to a gaseous fuel as methane. Coal reacts with hot steam to form CO and H_2. These gases can react further to give methane.

$$C_{(s)} + H_2O_{(g)} \xrightarrow{1000^oC} CO_{(g)} + H_{2(g)}$$

$$CO_{(g)} + 3H_{2(g)} \longrightarrow CH_{4(g)} + H_2O_{(g)}$$

$$CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$$

Write equilibrium constant expression for this reaction.

Problem Solving Strategy

1. Write products in the numerator and reactants in the denominator in square brackets.
2. Raise each concentration to the power that corresponds to the co-efficient of each species in the balanced chemical equation.

Solution:

$$K_c = \frac{[CH_4][H_2O]}{[CO][H_2]^3}$$

Self Assessment Exercise 9.2

1. Following reaction can occur during lightning storms.

$$3O_{2(g)d} \rightleftharpoons 2O_{3(g)}$$

Derive equilibrium constant expression for this reaction.

2. Write equilibrium constant expression for the following reactions.

a. $4HCl_{(g)} + O_2(g) \rightleftharpoons 2H_2O_{(g)} + 2Cl_{2(g)}$

b. $CH_3COOH_{(\ell)} + C_2H_5OH_{(\ell)} \rightleftharpoons CH_3COOC_2H_{5(\ell)} + H_2O_{(\ell)}$

c. $2HF_{(g)} \rightleftharpoons H_{2(g)} + F_{2(g)}$

d. $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

Reading

9.2.1. Conditions for Equilibrium

Equilibrium is reached when pure reactants, pure products or a mixture of reactants and products is first placed in a closed container. In any such case, the forward and reverse action in the container will occur at the same rate. This leads to a situation where the concentration of reactants and products remain the same indefinitely, for an indefinite time so long the following conditions are observed:

1. Concentration of the reactant or product remains unchanged.
2. Temperature of the system remains constant.
3. Pressure or volume of the system remains constant.

9.2.2 Ways to Recognize Equilibrium

When constant concentration of products and reactants is observed, the reaction is at equilibrium. This can be done by both physical as well as chemical methods such as titration, spectroscopy etc. You will learn these methods in detail in Grade XI.

9.3 EQUILIBRIUM CONSTANT AND ITS UNITS

Equilibrium constant may or may not have units. In the equilibrium expression each figure within a square bracket represents the concentration in mol dm^{-3}. The units of K_c therefore depend on the form of equilibrium expression.

Example: 9.3. Determining units of equilibrium constants

Determine the units of equilibrium constants for the following reactions.

(i) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

(ii) $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

(iii) $2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$

Problem Solving Strategy

1. Write the equilibrium constant expression.
2. Write units of concentration of each species i.e. mol dm^{-3} within the square bracket.
3. Simplify the expression.

Solution:-

(i) $K_c = \frac{[HI]^2}{[H_2][I_2]}$

$$K_c = \frac{[moldm^{-3}]^2}{[moldm^{-3}][moldm^{-3}]}$$

K_c = no units

K_c has no units when the total number of moles of reactants is equal to the total number of moles of products in a balanced chemical equation.

Do you know?
A catalyst is a substance which increases the rate of a chemical reaction. Catalysts reduce the time taken to reach equilibrium, but they have no effect on the position of equilibrium once this is reached.

(ii) $K_c = \frac{[NO_2]^2}{[N_2O_4]}$

$$K_c = \frac{[mol\ dm^{-3}]^2}{[mol\ dm^{-3}]}$$

$$K_c = mol\ dm^{-3}$$

(iii) $K_c = \frac{[NO_2]^2}{[NO]^2[O_2]}$

$$K_c = \frac{[mol\ dm^{-3}]^2}{[mol\ dm^{-3}]^2[mol\ dm^{-3}]}$$

$$K_c = dm^3 mol^{-1}$$

Science Titbits
The addition of water to the concentrated sulphuric acid produces a vigorous reaction, which often causes acid droplets to spew in all directions. For this reason this must be avoided. Add water to dilute acid.

Examples (ii) and (iii) show that K_c has units. A close observation reveals that reversible reaction in which, the total number of moles of reactants is different from the total number of moles of products in a balanced chemical equation, K_c has units.

Self Assessment Exercise 9.3

Determine the units of equilibrium constants for the following reactions.

1. $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$
2. $H_{2(g)} + CO_{2(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$
3. $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$
4. $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$

Reading

9.4 IMPORTANCE OF EQUILIBRIUM CONSTANT

Equilibrium constant for a reaction can be used to predict many important features of a chemical reaction. It can be used to

(a) determine the equilibrium concentration of equilibrium mixture knowing the initial concentration of reactants.
(b) predict the direction of a chemical reaction.
(c) Predict the extent of a chemical reaction.
(d) predict the effect of change in conditions of the chemical reaction on the equilibrium state.

You will learn about these features in detail in grade XI. Industrial chemists take help from the effects of changes in conditions such as concentrations, temperature, pressure etc. They choose conditions needed for the desired products.

Nitrogen and Oxygen are main gases of the air. They are effectively converted in the large scale production of many important chemicals such as ammonia, sulphuric acid etc.

Ammonia is produced by the reaction of nitrogen with hydrogen at 400ºC, 200 atm pressure and in the presence of a catalyst.

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

This process is known as Haber process . This is a reversible process and produces only 33% NH_3 at equilibrium. The high pressure is used to favour the formation of ammonia. Then, cooling the equilibrium mixture gives 98% ammonia.

Sulphuric acid is produced on a large scale by the contact process. In this process sulphur is converted into sulphur dioxide.

$$S_{(s)} + O_{2\,(g)} \longrightarrow SO_{2\,(g)}$$

Sulphur dioxide is purified and further oxidized at 450°C and 200 atm pressures in the presence of Pt or V_2O_5 as catalyst.

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

This reaction is a reversible reaction. Here again by the application of principles of chemical equilibrium, maximum amount of SO_2 is converted into SO_3. Sulphur trioxide is then converted into 100% pure sulphuric acid.

Society, Technology and Science

Although reversible reactions do not complete, yet such reactions are not economical for the large scale production of chemicals. However, progress of the science has enabled us to deal with such reactions and obtain maximum amount of products from reversible reactions. An important principle called **Le Chatellier's principle** is very useful about chemical equilibrium systems, it says that **if you impose a change in concentration, temperature or pressure on a chemical system at equilibrium, the system responds in a way that opposes the change.** With the application of this principle, components of air i.e N_2 and O_2 can be used successfully in producing important chemicals, ammonia and sulphuric acid in 98% yield. Both these processes involve reversible reactions, so inadequate amount of products are formed under normal conditions.

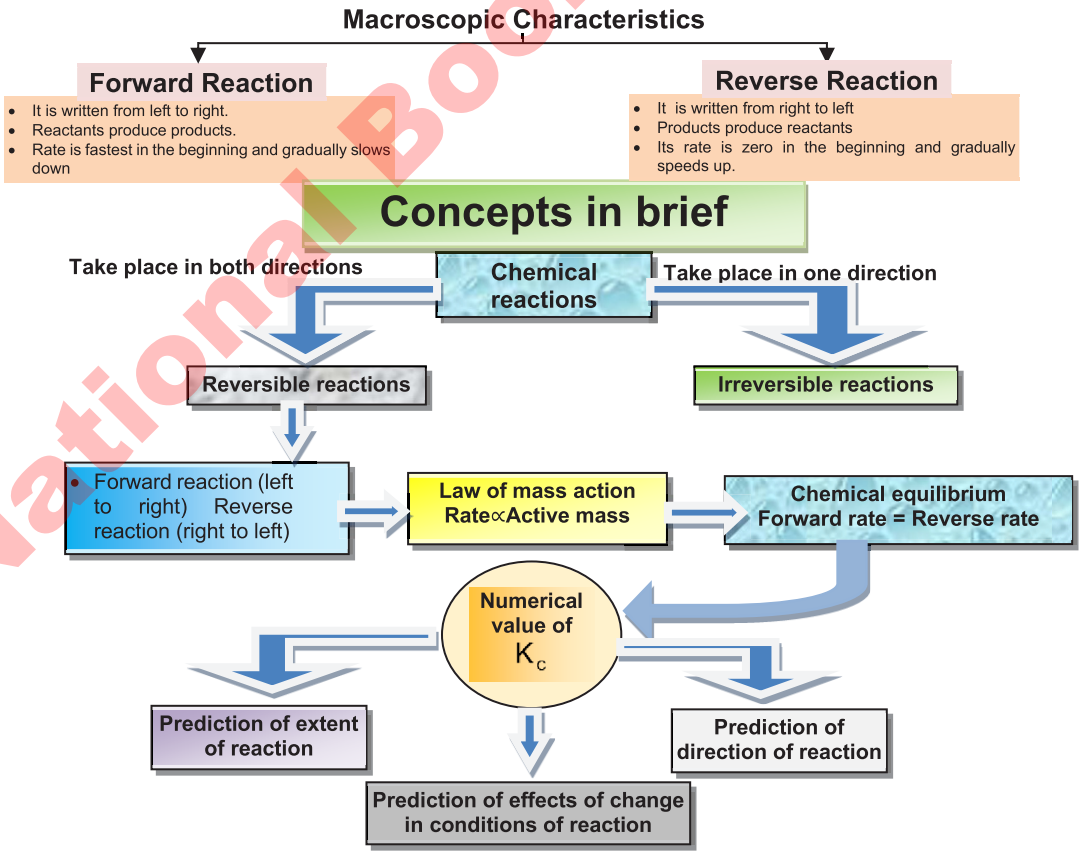
$$2SO_{2(g)} + O_{2(g)} \underset{450^oC,200atm}{\overset{V_2O_5}{\rightleftharpoons}} 2SO_{3(g)}$$

Sulphur dioxide Oxygen Sulphur trioxide

$$N_{2(g)} + 3H_{2(g)} \underset{400^oC,200atm}{\overset{Fe}{\rightleftharpoons}} 2NH_{3(g)}$$

Nitrogen Hydrogen Ammonia

As such these reactions are uneconomical. However, Le Chatelliers's principle has made it possible to get maximum amount of products. First, equilibrium is established in the presence of catalyst in minimum time and then by increasing pressure and decreasing temperature, equilibrium is shifted towards right. Such conditions tend to increase the yield of NH_3 and SO_3 to about 98%.



Key Points

- A reaction in which the products can react together to re-form the original reactants is called reversible reaction.
- A state of a chemical reaction in which forward and reverse reactions take place at the same rate is called chemical equilibrium.
- The law of mass action states that the rate at which a substance reacts is directly proportional to its active mass and the rate at which the reaction proceeds is directly proportional to the product of the active masses of the reactants.
- The term **"active mass"** represents the concentration of reactants and products in $moldm^{-3}$ for a dilute solution.
- Equilibrium constant is defined as the ratio of the product of concentration of products to the product of concentration of reactants each raised to the power equal to the coefficient in the balance chemical equation.

References for additional information

- Chemistry, Roger Norris, Lawrie Ryen and David Acaster.
- Principals of chemical equilibrium, Kenneth Denbigh.

Review Questions

1. Encircle the correct answer.

(i) Which is true about the equilibrium state?

(a) The forward reaction stops.
(b) The reverse reaction stops.
(c) Both forward and reverse reactions stop.
(d) Both forward and reverse reactions continue at the same rate.

(ii) When a mixture of H_2 and I_2 is sealed in a flask and temperature is kept at 25ºC, following equilibrium is established.

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

Which substance or substances will be present in the equilibrium mixture?

(a) H_2 and I_2
(b) HI only
(c) H_2 only
(d) H_2, I_2 and HI

(iii) What are the units for

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$$

(a) mol.dm^{-3}

(b) mol^2. dm^{-6}

(c) dm^3.mol^{-1}

(d) No units

(iv) Which of the following reaction will not have any units for K_c?

(a) $H_{2(g)} + CO_{2(g)} \rightleftharpoons H_2O_{(g)} + CO_{(g)}$

(b) $N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$

(c) $2A_{(g)} + B_{(g)} \rightleftharpoons 3AC_{(g)}$

(d) All of these

(v) Concentration of reactants and products at equilibrium remains unchanged if

(a) concentration of any reactant or product is not changed.

(b) temperature of the reaction is not changed.

(c) pressure or volume of the system is not changed.

(d) all of the above are observed

(vi) Which of the following does not happen, when a system is at equilibrium state?

(a) forward and reverse reactions stop.

(b) forward and reverse rates become equal.

(c) concentration of reactants and products stop changing.

(d) reaction continues to occur in both the directions.

(vii) For which reaction, K_c has units of mol.dm^{-3}.

(a) $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

(b) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

(c) $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$

(d) $2ICl_{(g)} \rightleftharpoons I_{2(g)} + Cl_{2\,(g)}$

(viii) In an irreversible reaction equilibrium is

(a) established quickly

(b) established slowly

(c) never established

(d) established when reaction stops.

(ix) Active mass means

(a) total mass of reactants

(b) total mass of products

(c) total mass of reactants and products

(d) mass of substance in moles per dm^3 in a dilute solution

(x) For a reversible reaction

$$K_c = \frac{[C]^2}{[A][B]}$$

Which substance is product of the reaction?

(a) A

(b) B

(c) Both A and B

(d) C

2. Give short answer.

(i) Differentiate between forward and reverse reactions.

(ii) What is chemical equilibrium?

(iii) Write the law of Mass Action.

(iv) Write down the conditions for equilibrium.

(v) What is the importance of equilibrium constant for a chemical reaction?

3. Following reaction can occur during lightning storms

$$3O_{2(g)} \rightleftharpoons 2O_{3(g)}$$

For this reaction write

(i) Equilibrium constant expression.

(ii) Determine the units of equilibrium constant.

(iii) Forward and reverse reactions.

4. Coal reacts with hot steam to form CO and H_2. These substances react further in the presence of a catalyst to give methane and water vapour.

$$CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$$

(i) Write forward and reverse reactions for it.

(ii) Derive K_C expression for the reaction.

(iii) Determine units for K_C

5. Write equilibrium constant expression for each of the following reactions.

(i) $H_2O_{(g)} \rightleftharpoons H_{2(g)} + \frac{1}{2}O_{2(g)}$

(ii) $CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$

(iii) $COCl_{2(g)} \rightleftharpoons CO_{(g)} + Cl_{2(g)}$

(iv) $4HCl_{(g)} + O_{2(g)} \rightleftharpoons 2Cl_{2(g)} + 2H_2O_{(g)}$

6. Determine the units of equilibrium constants for the following reactions.

(i) $COCl_{2(g)} \rightleftharpoons 2CO_{(g)} + Cl_{2(g)}$

(ii) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

(iii) $2H_{2(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)}$

(iv) $N_{2(g)} + 2O_{2(g)} \rightleftharpoons 2NO_{2(g)}$

7. State the ways that equilibrium can be recognized.

8. Describe the macroscopic characteristics of an equilibrium reaction.

Think-Tank

1. Bromine chloride (BrCl) decomposes to form chlorine and bromine. For this reaction write.

(i) Chemical equation

(ii) K_c expression

(iii) Units of K_c

2. K_C expression for a reaction is given below

$$K_c = \frac{[NO_2]^2}{[N_2O_4]}$$

Choose reactant and product to derive the units of K_C for this reaction.

3. For which of the following reactions are both reactants and products likely to be found when the reaction appears to be complete. Justify.

(i) $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

(ii) $2HF_{(g)} \rightleftharpoons H_{2(g)} + F_{2(g)}$

Cobalt chloride forms pink crystals ($CoCl_3.6H_2O$). When they are heated water is evolved and they turn blue ($CoCl_3$). Can you use Cobalt chloride as a test for water, argue.

$$CoCl_3.6H_2O \rightleftharpoons CoCl_3 + 6H_2O$$

10

ACIDS, BASES AND SALTS

After completing this lesson, you will be able to:

This is 13 days lesson (period including homework)

- Define and give examples of Arrhenius acids and bases.
- Use the Bronsted-Lowry theory to classify substances as acids or bases, or as proton donors or proton acceptors.
- Classify substances as Lewis acid or bases.
- Write the equation for self-ionization of water.
- Given the hydrogen ion or hydroxide ion concentration, classify a solution as neutral, acidic, or basic.
- Complete and balance a neutralization reaction.
- Use litmus paper, pH paper and other indicators for measuring pH of solutions.
- Perform acid base titrations and related calculations.
- Identify areas of work for analytical chemists.
- Explain why the quantity of preservatives in food is restricted by government regulations.
- Explain pH-dependent foods.
- Explain process of etching in arts and industry.
- Explain the reactions between industrial pollutants and atmospheric water leading to formation of acids.
- Describe harmful effects of acid rain.
- Explain stomach acidity.

Reading

INTRODUCTION:

You frequently use acids and bases in every aspect of life. For instance, vinegar, aspirin, lemon juice, cola drinks, apple, tomato and toilet bowl cleaner contain acids. Substances such as drain cleaner, antacid tablets, baking powder, washing soda etc. contain bases. You eat and drink certain acids and bases, and your bodies produce them. From "**acid indigestion**" to "**acid rain**" the word **acid** occurs frequently in the news and advertisements.

What is an acid rain? This chapter will enable you to understand which substances are called acids and which are called bases. How they are classified? What happens when an acid reacts with a base? Why do we use lemon juice on fish? In this chapter you will learn some of the chemistry of acids and bases. This will help you to gain a better understanding of these important classes of compounds. What do we mean by the pH of a solution such as that of acid rain? Acids are widely used in the manufacturing of fertilizers and in food industry.

Society Technology and Science

Acid rain can damage trees, kill huge areas of forest. It washes out aluminum ions from the soil. These aluminum ions run into rivers, lakes and ponds. Aluminum is very toxic to fish and other aquatic life. They cannot survive in it and may be killed. Acid rain can also damage buildings and statues. The acid reacts with carbonates in lime stone. The lime stone dissolves and the statue gradually crumbles away. Thus acid rain is an important environmental issue.

Do you know?

Sulphur dioxide and oxides of nitrogen are also produced by smoking of cigarettes. Smokers breathe in a lot of sulphur dioxide. Over long period of time, they have an increased risk of suffering from cold, bronchitis and asthma.

10.1 CONCEPTS OF ACIDS AND BASES

Acids and bases are generally recognized by their characteristic properties. Table 10.1 shows such properties.

Table 10.1 Some characteristic properties of acids and bases

Sr. No.	Property	Acid	Base
1	Taste	Sour	Bitter
2	Effect on blue litmus	Turns red	No effect
3	Effect on red litmus	No effect	Turns blue
4	Effect on skin	Corrosive	Corrosive
5	Electrical conductivity	Aqueous solutions conduct electricity	Aqueous solutions conduct electricity

10.1.1 Arrhenius Concept of Acids and Bases

In 1887, a Swedish chemist Svante Arrhenius proposed the first successful theory of acids and bases. According to this theory

An acid is a substance that ionizes in water to produce H^+ions and a base is a substance that ionizes in water to produces OH^-ions.

For example,

$$HCl_{(g)} \xrightleftharpoons{H_2O} H^+_{(aq)} + Cl^-_{(aq)}$$

$$NaOH_{(s)} \xrightleftharpoons{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

Which substances in the following reactions are acids or bases?

$$HNO_{3\,(l)} \xrightleftharpoons{H_2O} H^+_{(aq)} + NO_3^{-1}{}_{(aq)}$$

$$H_2SO_{4\,(l)} \xrightleftharpoons{H_2O} 2H^+_{(aq)} + SO_4^{-2}{}_{(aq)}$$

$$KOH_{(s)} \xrightleftharpoons{H_2O} K^+_{(aq)} + OH^-_{(aq)}$$

$$NH_4OH_{(aq)} \xrightleftharpoons{H_2O} NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

Table 10.2 shows some common acids and table 10.3 shows some common bases.

Table 10.2 Some Common Acids

Name	Formula	Common use
Hydrochloric acid	HCl	Cleaning of metals, bricks and removing scale from boilers
Nitric acid	HNO_3	Manufacture of fertilizers, explosives
Sulphuric acid	H_2SO_4	Manufacture of many chemicals, drugs, dyes, paints and explosives.
Phosphoric acid	H_3PO_4	Manufacture of fertilizers, acidulant for food

Table 10.3 Some Common Bases

Name	Formula	Common use
Sodium hydroxide	$NaOH$	Soap making, drain cleaners
Potassium hydroxide	KOH	Making liquid soap, shaving cream
Calcium hydroxide	$Ca\,(OH)_2$	Making mortar, plasters, cement
Magnesium hydroxide	$Mg(OH)_2$	Antacid, laxative

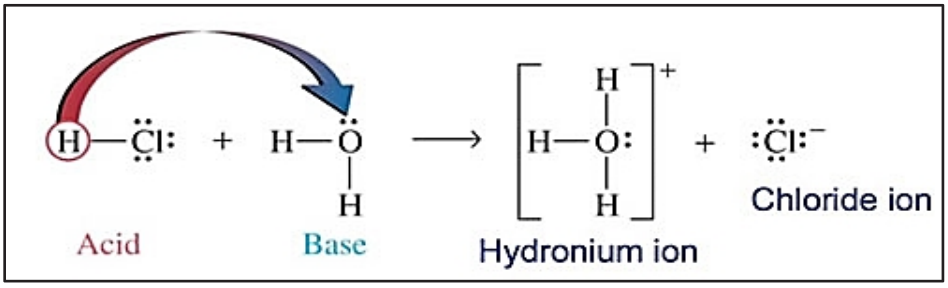
10.1.2 The Bronsted-Lowery Concept of Acids and Bases

Arrhenius theory has its limitations. It applies to aqueous solutions. It does not explain why compounds such as CO_2, SO_2 etc., are acidic. Why substances like NH_3, are bases? There is no H in CO_2 and OH in NH_3.

In 1923 J.N Bronsted and T.M Lowery independently proposed another theory to overcome the shortcomings of Arrhenius theory. This theory is known as **Bronsted-Lowery theory**.

According to this theory **an acid is a proton donor and a base is a proton acceptor.**

Consider the following example



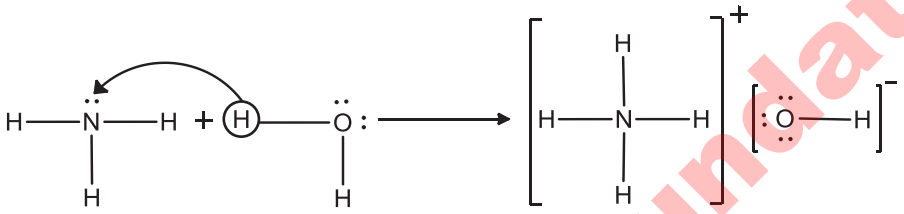
Q.1. Which substance is donating proton? _____

Q. 2. Which substance is accepting proton? _____

Q. 3. Which substance is acid? _____

Q. 4. Which substance is base? _____

Where does the OH^- come from in the ionization of bases such as ammonia? The Arrhenius theory is inadequate to answer this question, but the Bronsted-Lowry theory explains how ammonia acts as a base in water. Ammonia is a gas at room temperature. When it is dissolved in water, the following reaction occurs.



Which substance is donating proton, NH_3 or H_2O? Which substance is proton acceptor? All the acids included in the Arrhenius Theory are also acids in the Bronsted-Lowery Theory. However, all the bases included in Bronsted-Lowery theory except OH^- are not Arrhenius bases. Consider above two examples. In one example, water molecule accepts a proton and in the other water donates a proton. This means water behaves like an acid as well as a base. It is amphoteric in nature. Substances that react with both acids and bases are called amphoteric substances.

Society Technology and Science

Fossils Fuels contain small amounts of sulphur and nitrogen. They produce sulphur dioxide and oxides of nitrogen when the fuel is burned. Large amounts of these oxides are released from coal-burning factories and power stations. They react chemically with the water vapours in clouds and oxygen in the air, forming acids.

$$SO_{2(g)} + \frac{1}{2}O_{2(g)} + H_2O_{(l)} \longrightarrow H_2SO_{4(aq)}$$

$$4NO_{2(g)} + O_{2(g)} + 2H_2O_{(l)} \longrightarrow 4HNO_{3(aq)}$$

These acids mix up with rain drops and fall as acids rain or acid snow.

Example 10.1: Classify substances as acids or bases or as proton donor or proton acceptor

Identify Bronsted-Lowery acids or bases in the following reactions.

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

$$H_2O + NH_3 \longrightarrow NH_4^+ + OH^-$$

Problem solving strategy:

1. An acid is a proton donor. After donating proton, an acid forms a negative ion.
2. A base is a proton acceptor. After accepting proton from an acid it forms a positive ion.

Solution:

1. Because HCl is converted to Cl^- by donating proton, HCl is an acid.
2. Because H_2O accepts the proton that HCl donates and forms H_3O^+, *water* is a base.
3. H_2O is converted to OH^- by donating a proton, so H_2O is an acid. Because NH_3 accepts the proton and forms NH_4^+ so it is a base.

Self Assessment Exercise 10.1

Identify Bronsted acids and Bronsted bases in the following reactions.

1. $H_2SO_4 + H_2O \rightleftharpoons HSO_4^- + H_3O^+$
2. $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$
3. $H_2S + NH_3 \rightleftharpoons NH_4^+ + HS^-$

Reading

10.1.3 Lewis Concept of Acids and Bases:

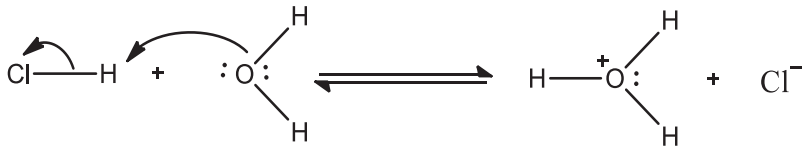
Certain substances like SO_2, CO_2, CaO, BF_3 etc. behave as acids or bases although they do not have ability to donate or accept protons. Nature of such substances cannot be explained by Arrhenius theory or the Bronsted-Lowry theory.

In 1923, G.N Lewis proposed an acid base theory that focuses on reaction. This concept is more general than either the Arrhenius theory or the Bronsted - Lowery theory.

A Lewis acid is substance that can accept a pair of electrons to form a coordinate covalent bond.

A Lewis base is a substance that can donate a pair of electrons to form a coordinate covalent bond.

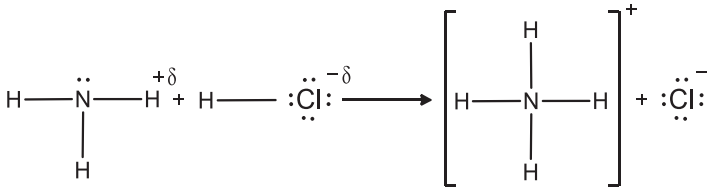
In a Lewis acid-base reaction a coordinate covalent bond is formed between the acid and the base. Consider the following reaction.



Electron pair acceptor Electron pair donor

(i) Which species is donating an electron pair?
(ii) Which species is accepting an electron pair?
(iii) Which species is a Lewis acid?
(iv) Which species is a Lewis base?

This theory can explains gas phase neutralization reactions.

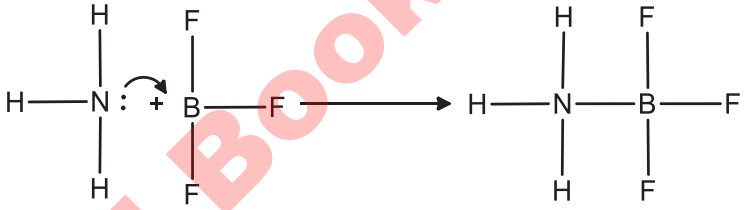


Nitrogen atom in ammonia donates an electron pair to H- atom in HCl. Which species in Lewis acid? HCl or NH_3.

The Lewis structure demands that the central atom or atom of Lewis acid has a deficiency of an electron pair and can accommodate an unshared electron pair. On the other hand, the central atom of a Lewis base has complete octet possessing one or more unshared electron pairs. Hence base has an ability to donate an unshared electron pair.

Example 10.2: Classifying substances as Lewis acids or Lewis bases.

Identify the Lewis acid and Lewis base in the following reactions.

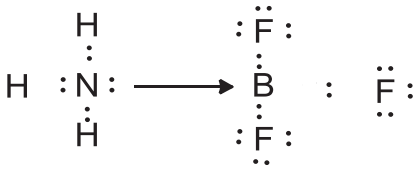


Problem Solving Strategy

1. Draw electronic structures of both the species.
2. Look for the species that has a lone - pair of electron or negative charge. Such a species has complete octet, so it does not need any electron. It can however, donate an electron pair. This species is a Lewis base.
3. Look for the species that can accommodate an electron pair. Such a species has incomplete octet. So this species can accept an electron pair. This species is a Lewis acid.

Solution

(i)



(ii) NH_3 has a lone pair on N-atom. So it is electron pair donor. NH_3 is a Lewis base.

(iii) Boron in BF_3has incomplete octet. It has six electrons (3 electron pairs). So it needs an electron pair to complete its octet. Hence BF_3 is an electron pair accepter or Lewis acid.

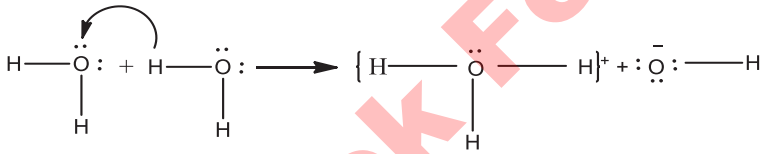
Self Assessment Exercise 10.2

Identify the Lewis acid and the Lewis base in the following examples.

1. $Cl^- + AlCl_3 \longrightarrow [AlCl_4]^-$
2. $H^+ + OH^- \longrightarrow H_2O$

10.2. SELF-IONIZATION OF WATER – THE pH SCALE

Water molecules are highly polar. Occasionally, the collisions between water molecules are energetic enough to transfer a proton from one water molecule to another.



A water molecule that donates or loses a proton becomes a negatively charged hydroxide ion OH^-. The other water molecule which gains or accepts the proton becomes positively charged hydronium ion, H_3O^+.

This reaction can be written as

$$2H_2O \longrightarrow H_3O^+ + OH^-$$

The reaction in which two water molecules produce ions is called as the self-ionization or auto-ionization of water. This reaction can also be written as a simple ionization of water.

$$H_2O_{(l)} \longrightarrow H^+{}_{(aq)} + OH^-{}_{(aq)}$$

Hydrogen ion Hydroxide ion

Water is a weak electrolyte. The self-ionization of water occurs to a very small extent. At 25ºC the experimentally determined concentrations of H^+ ions and OH^- ions are as follows.

$$[H^+] = [OH^-] = 1 \times 10^{-7} M$$

You can write equilibrium constant expression for the self-ionization of water as follows.

$$K_c = \frac{[H^+][OH^-]}{[H_2O]}$$

Since $H_2O$is a weak electrolyte, so the concentration of $[H_2O]$ will remain constant.

$$K_c[H_2O] = [H^+][OH^-]$$

$$K_w = [H^+][OH^-]$$

Where $K_w = K_c[H_2O]$ is called ionization constant for water. It is also called the ion- product for water. For water

$$K_w = (1 \times 10^{-7})(1 \times 10^{-7}) = 1 \times 10^{-14} at\ 25^oC$$

in pure water, the concentration of H^+ and OH^- ions are equal.

$$[H^+] = [OH^-] = 1 \times 10^{-7} at\ 25^oC$$

In 1909, the Danish biochemist Soren Sorenson proposed a convenient method to express such a small concentration of H^+ ions and OH^- ions by pH or pOH

pH is defined as the negative logarithm of the molar concentration of H^+ ions in aqueous solutions.

$$pH = -log[H^+]$$

For pure water at 25°C

$[H^+] = 1 \times 10^{-7}M$, $[OH^-] = 1 \times 10^{-7}M$

$$pH = -log(1 \times 10^{-7}) = 7$$

Thus pH of water is 7. All aqueous solutions with pH= 7 at 25°C are neutral. If pH is less than 7, the solutions become acidic, $[H^+]$ increases and $[OH^-]$ decreases.

Society, Technology and Science

Certain plants grow successfully at a particular pH range

Plant	pH range
Apple	5.5 - 7.0
Broad Bean	6.5 - 7.0
Carrot	6.0 - 7.5
Onion	6.5 - 7.5
Potato	5.5 - 6.5
Tomato	5.5 - 7.0

What is the importance of K_w?

K_w is temperature dependent. In any aqueous solution at 25°C, no matter what does it contain the product of H^+ ion concentration and OH^- ion concentration is always equal to 1.0×10^{-14}. This means that if $[H^+]$ increases, the $[OH^-]$ must decrease so that the product of the two is still 1.0×10^{-14}. What will happen if $[OH^-]$ increases?

When $[H^+] = [OH^-] = 1 \times 10^{-7}$, solution is neutral

When $[H^+] > 1 \times 10^{-7}$, solution is acidic

When $[H^+] < 1 \times 10^{-7}$, solution is basic

If pH is greater than 7, the solution is basic. As solution becomes basic, $[OH^-]$ increases and $[H^+]$ decreases. If pH is less than 7, the solution is acidic. As solution become acidic, $[H^+]$increases and $[OH^-]$decreases.

Figure 10.1 shows pH scale and pH values of some common substances.

pH	Examples of solutions
0	Battery acid, strong hydrofluoric acid
1	Hydrochloric acid secreted by stomach lining
2	Lemon juice, gastric acid, vinegar
3	Grapefruit juice, orange juice, soda
4	Tomato juice, acid rain
5	Soft drinking water, black coffee
6	Urine, saliva
7	"Pure" water
8	Sea water
9	Baking soda
10	Great Salt Lake, milk of magnesia
11	Ammonia solution
12	Soapy water
13	Bleach, oven cleaner
14	Liquid drain cleaner

Figure 10.1: pH scale and pH values of common substances

Example 10.3: Classifying a solution as neutral, acidic or basic

1. Unrefined hydrochloric acid is used to clean stone buildings and swimming pools. If the $[H^+]$ in a solution of HCl is 1×10^{-6} M. Is the solution acidic, basic or neutral?
2. Solution hydroxide (NaOH) is commonly used as a drain cleaner. If the concentration of OH^- in a solution of NaOH is 1.0×10^{-5} M. Is the solution acidic basic or neutral?

Problem Solving Strategy:

1. Compare the given concentrations of $[H^+]$ ions in solution with that of neutral water.
2. If $[OH^-]$ is given, calculate $[H^+]$ from $K_w = [H^+][OH^-]$.

3. Remember that

If $[H^+] = [OH^-] = 1 \times 10^{-7}$ solution is neutral.

If $[H^+] > 1 \times 10^{-7}$, solution is acidic.

If $[H^+] < 1 \times 10^{-7}$, solution is basic.

Solution:

1. $[H^+] = 1.0 \times 10^{-6} M > 1.0 \times 10^{-7}$ M, the solution is acidic.
2. $[OH^-] = 1.0 \times 10^{-5} M$

   $[H^+]$ = ?

   $K_w = [H^+][OH^-]$.

   $1.0 \times 10^{-14} = [H^+]1.0 \times 10^{-5}$

   $[H^+] = 1.0 \times 10^{-9} M$

   Because $1.0 \times 10^{-9} M < 1.0 \times 10^{-7} M$, the solution is basic.

Self Assessment Exercise 10.3

1. A soft drink has $[H^+] = 3 \times 10^{-3} M$. Is the drink acidic drink neutral or basic?
2. Ordinary vinegar is approximately 1M CH_3COOH. Concentration of H^+ in it is 4.2×10^{-3} M. Is vinegar acidic, basic or neutral?
3. A student determines the $[OH^-]$ of milk of magnesia, a suspension of solid magnesium hydroxide in its saturated solution and obtains a value of 4.2×10^{-3}M. Is the solution acidic, basic or neutral?

Reading

10.2.1 The pH Scale

Chemists use a number scale from 0 to 14 to describe the concentration of H^+ions in a solution. It is known as pH scale. Figure 10.1 shows pH scale and pH values of some common substances.

- A pH of 7 indicates a neutral solution.
- Acids have pH less than 7.
- Bases have pH greater than 7.

Important Information

The optimum pH range of a swimming pool is 7.2 to 7.6 because in human tears, when the pH is outside this range, eye irritation can occur.

Teacher's Point

Teacher may give examples of applications of pH in daily life.

Measurement of pH

Scientist use different methods to measure pH of a solution. pH paper or universal indicator paper is used to measure pH of a solution. For this purpose pH paper is dipped in the solution. The colour that develops on the pH paper is compared to the colour corresponding to a known pH on the chart. Each colour is linked to a specific pH value. (Figure 10.2)

Figure 10.2: Colours of pH paper or universal indicator

One of the most commonly used methods in chemistry laboratory is the use of litmus paper. It is used to give a general indication of whether a solution is acidic or basic. Litmus paper may be red or blue. An acid turns blue litmus paper into red. A base turns red litmus paper into blue.

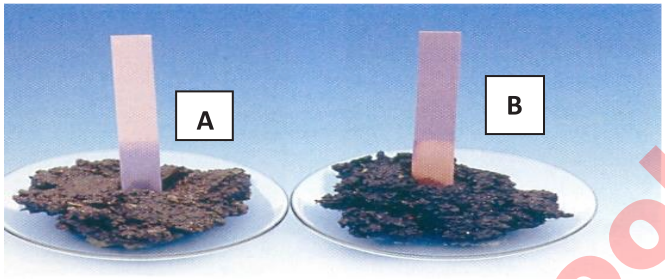


Figure 10.3: The soil sample A turns red litmus blue. The soil sample B turns blue litmus red. Which soil is acidic? Which soil is basic?

Society, Technology and Science

Acidity of stomach

The main component of digestive or gastric juice in the stomach is hydrochloric acid. Almost two litre of it is secreted each day by gastric glands. However sometimes too much acid is secreted in the stomach which causes indigestion. This is called acidity of the stomach.

Acid - base indicators are also used to estimate the pH of a solution. Indicators are intensely colored organic compounds. They change colour within small pH change and indicate the pH of solution by the colour. We add few drops of an indicator to an aqueous solution of unknown pH and measure pH of the solution from the resulting colour. (Figure 10.5)

Society Technology and Science

Analytical chemist measures pH of solutions. pH measurement has valuable applications. For instance, it helps analytical chemist to **(i)** to create soil conditions ideal for plant growth **(ii)** medical diagnosis**(iii)** maintaining the correct acid-base balance in swimming pools**(iv)** electroplating **(v)** manufacture of medicine etc. tap water and waste water.

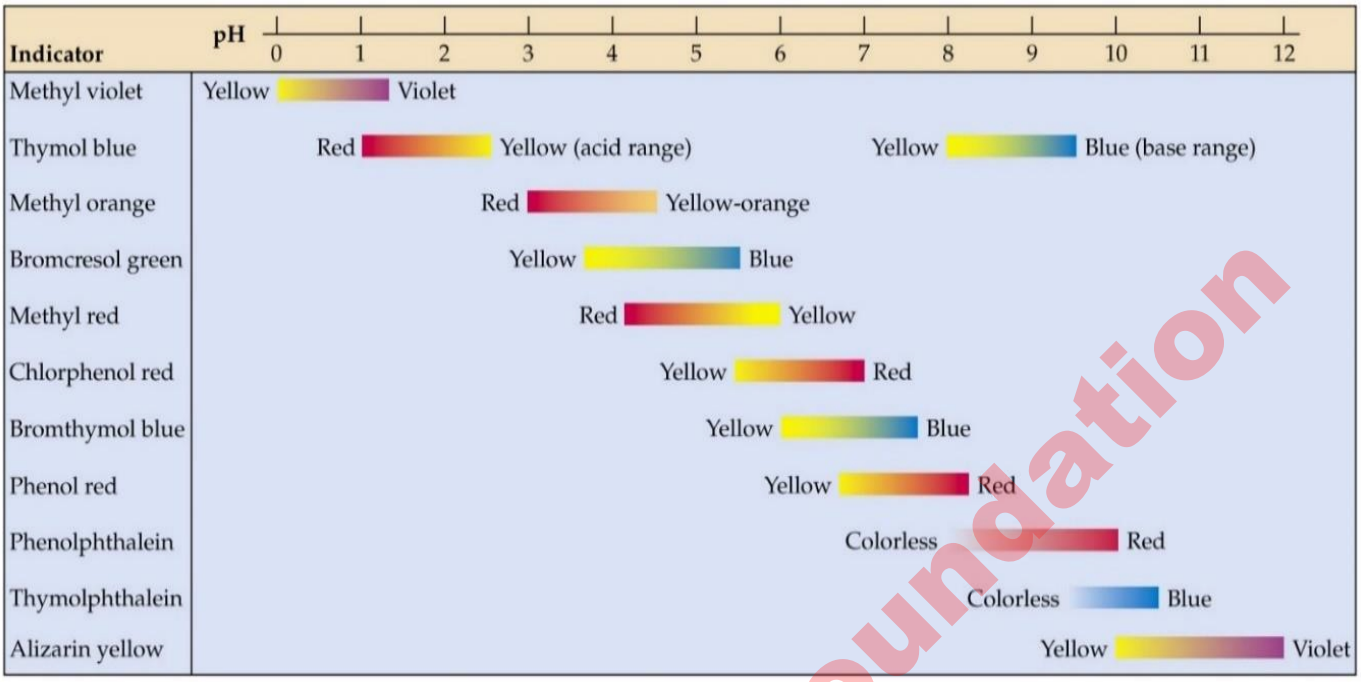


Figure 10.5 Colour changes of some acid base indicators

Methyl red changes color from red to yellow at pH 5. At what pH stage phenolphthalein changes its colour? At what pH stage bromothymol blue changes colour from yellow to blue?

Self Assessment Exercise 10.4

1. Write names of three acid - base indicators.
2. What is the colour of methyl red in solution of (i) pH =4 (ii) pH=9?
3. Bromothymol blue added to a solution imparts blue colour,
4. What is the pH of this solution? pH = 5 or 9

Reading

Table 10.3 pH ranges of some common indicators

Indicator	pH at which colour changes	Colour in acidic solution	Colour in basic solution
Methyl red	5.5	Red	yellow
Bromothymol blue	7	Yellow.	Blue
Phenolphthalein	9	Colourless	Pink

Activity 10.1

Use litmus paper, pH paper and other indicators for measuring pH of solutions

You will need:

- Lemon juice
- Vinegar
- Soap solution
- HCl solution
- NaOH solution

Use of litmus paper: Carry out the following

- Take each solution in separate beakers and write the name of each solution on each beaker.
- Take about 2-3 cm^3 of each solution in separate test tubes and dip red and blue litmus paper in each solution.
- Note the colour change in each case and record.

Result: This test will classify each solution as acid or base or has pH less than 7 or greater.

Use of pH paper:

- Take about 2-3 cm^3 each solution in separate test tubes and dip pH paper in each solution.
- Note the colour developed on pH paper.

Now compare this colour with the pH scale given in figure 10.2 and find pH of solution.

Complete the following table

Substance	pH
Lemon juice	
Vinegar	
Soap solution	
HCl solution	
NaOH solution	

Use of methyl orange

- Take about 2-3 cm^3 of each solution in separate test tubes and add 1-2 drops of methyl orange in each test tube and note the colour of solution.

Key:

Yellow colour indicates pH > 4

Red Colour indicates pH< 4

Complete the following table,

Substance	Colour of methyl orange	pH
Lemon juice		
Vinegar		
Soap solution		
HCl solution		
NaOH solution		

Society, Technology and Science

Etching is an art that uses acid to carve patterns into metal, glass and other materials. For this a piece of metal or glass is covered with wax, and then a design is etched on to the plate through the wax. The plate is then dipped into a tank of acid. The acid eats away at the exposed portion, which leaves behind textured mark. The plate is then taken out of the acid and cleaned. Ink can also be applied on etching to create colourful design.

SKILLS

Activity 10.2: Perform acid base titration and related calculations.

Activity 10.2

To standardize the given solution of hydrochloric acid

Note: Perform this activity in chemistry laboratory.

You will need:

- Burette, Pipette, burette stand, beakers, conical flash, glass rod.
- Standard 0.1M NaOH solution and phenolphthalein.

Chemical equation

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

n_1 = 1 mole n_2 = 1 mole

Carry out the following:

- Fit up a clean burette in the burette stand vertically.
- Fill burette with HCl solution up to zero mark.
- Take 10 cm^3 of NaOH solution in a conical flask with the help of pipette.
- Add few drops of phenolphthalein in it as indicator.
- Note the initial reading on the burette.
- Run the acid solution in the conical flask drop by drop, and shake the flask constantly.
- Go on adding the acid solution till the pink colour just disappears.
- Note down the final reading from the burette.
- The difference between the final and initial reading gives the volume of the acid used to neutralize 10.0 cm^3 of NaOH solution.
- Repeat the experiment to get three concordant readings.
- Find the mean volume of HCl solution used.

Observations and calculations

Suppose volume of HCl solution used = $V_1 = 10\ cm^3$

Molarity of HCl solution = $M_1 = ?$

Volume NaOH solution used = $V_2 = 10\ cm^3$

Molarity of NaOH solution = $M_2 = 0.1M$

No. of moles of HCl = $n_1 = 1$

No. of moles of NaOH = $n_2 = 1$

$$\frac{M_1 \times V_1}{n_1} = \frac{M_2 V_2}{n_2}$$

$$\frac{M_1 \times 10}{1} = \frac{0.1 \times 10}{1}$$

$$M_1 = 0.1\ M$$

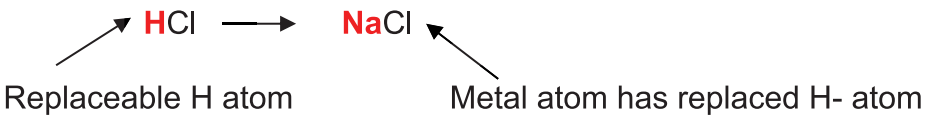
Result: Molarity of HCl solution is 0.l M

Do you know?

We make use of chemistry when we put lemon juice on fish. The unpleasant fishy odour is due to amines. The citric acid present in lemon juice converts amines to non-volatile salts, thus reducing the odour.

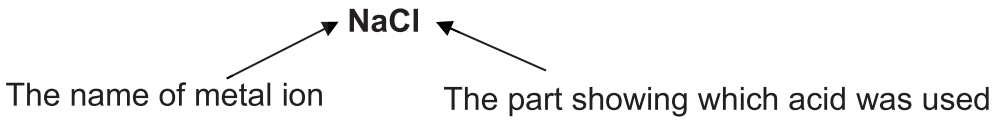
10.3 SALTS

An acid contains replaceable hydrogen atoms. When these are completely or partially replaced by metal atoms, a compound called salt is formed.



Which is a salt HCl or NaCl?

Salts are ionic compounds. The first part of the name is of the metal ion and second part of the name is of the negative part of the acid. g. Sodium Chloride.



Which acid forms$NaNO_3$? Which acid forms $CaSO_4$? Table 10.4 shows some common acids and their salts.

Table 10.4 Some common acids and their salts

Acid	Salt name	Example
Hydrochloric HCl	Chloride Cl^-	$NaCl, KCl, CaCl_2$
Nitric HNO_3	Nitrate NO_3^{-1}	$NaNO_3, KNO_3, Ca(NO_3)_2$
Sulphuric H_2SO_4	Sulphate SO_4^{-2}	$Na_2SO_4, K_2SO_4, CaSO_4$
Phosphoric H_3PO_4	Phosphate PO_4^{-3}	$Na_3PO_4, K_3PO_4, Ca_3(PO_4)_2$

Neutralization is the specific term used for the reaction of acids with bases.

$$Acid + Base \longrightarrow Salt + Water$$

$$\boldsymbol{HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}}$$

Neutralization is the reaction between H^+ ions of an acid and OH^- ions of a base.

$$H^+{}_{(aq)} + OH^-{}_{(aq)} \longrightarrow H_2O_{(l)}$$

Reactions of acids with bases are used in the experimental procedure of titration. You will do this work in your laboratory. (Activity 10.2)

Example 10.4: Writing complete and balanced chemical equation for a neutralization reaction

1. Soda ash, Na_2CO_3 is used to make glass. It can be made by the reaction of carbonic acid $(H_2CO_3)$and Sodium hydroxide$(NaOH)$. Write complete and balanced chemical equation for this neutralization reaction.

2. Barium nitrate $Ba\ (NO_3)_2$is used to produce a green colour in firework. It can be made by the reaction of nitric acid $(HNO_3)$with barium hydroxide, $Ba(OH)_2$. Write complete and balanced chemical equation for this neutralization reaction.

Problem Solving Strategy

1. Write word equation describing the neutralization reaction.
2. Write chemical formulas of the substances involved in the chemical reaction. Salt consists of cations from the base and anions from the acid.
3. During neutralization reaction one H - atom of an acid combines with one OH group of the base to form one water molecule. So, place a suitable number before acid or base to balance H in acid with OH in base.
4. Balance remaining equation by inspection method.
5. Show the state of each of the substance involved.

Solution

1. Carbonic acid + Sodium hydroxide ⟶Sodium carbonate + water

   $H_2CO_3 + NaOH \longrightarrow Na_2CO_3 + H_2O$

   H_2CO_3 contains two neutralizable H-atoms and NaOH contain only one OH. So multiply NaOH by 2.

   $H_2CO_3 + 2NaOH \longrightarrow Na_2CO_3 + H_2O$

   Now balance H-atoms on the right side by placing 2 before H_2O.

   $H_2CO_3 + 2NaOH \longrightarrow Na_2CO_3 + 2H_2O$

   $H_2CO_{3(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + 2H_2O_{(l)}$

2. Nitric acid + Barium hydroxide ⟶ Barium nitrate + water.

   $HNO_3 + Ba(OH)_2 \longrightarrow Ba(NO_3)_2 + H_2O$

   HNO_3 contains one neutralizable H-atom and $Ba(OH)_2$ contains two OH-groups. So multiply HNO_3 by 2.

   $2HNO_3 + Ba(OH)_2 \longrightarrow Ba(NO_3)_2 + H_2O$

   Now balance H-atoms on the right side by placing 2 before H_2O.

   $2HNO_3 + Ba(OH)_2 \longrightarrow Ba(NO_3)_2 + 2H_2O$

   $2HNO_{3(aq)} + Ba(OH)_{2(aq)} \longrightarrow Ba(NO_3)_{2(aq)} + 2H_2O_{(l)}$

Self Assessment Exercise 10.5

1. Hydroxides such as $Mg(OH)_2$ called milk of magnesia is used as antacid. It neutralizes excess stomach acid (HCl). Write complete and balanced chemical equation for this neutralization reaction?
2. Hydrochloric acid (HCl) and Potassium hydroxide (KOH) react and produce potassium chloride. Write complete and balanced chemical equation for this neutralization reaction?
3. Balance following neutralization reactions

(i) $H_2SO_{4(aq)} + NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)}$

(ii) $H_3PO_{4(aq)} + NaOH_{(aq)} \longrightarrow Na_3PO_{4(aq)} + H_2O_{(l)}$

Some acids form more than one salts. For example Carbonic acid (H_2CO_3) has two replaceable H-atoms. Its partial neutralization forms hydrogen carbonate. On complete neutralization it forms carbonate.

$$H_2CO_{3(aq)} + NaOH_{(aq)} \longrightarrow NaHCO_{3(aq)} + H_2O_{(l)}$$

$$H_2CO_{3(aq)} + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + H_2O_{(l)}$$

$$H_3PO_{4(aq)} + NaOH_{(aq)} \longrightarrow NaH_2PO_{4\,(aq)} + H_2O_{(l)}$$

A salt containing a replaceable H- atom or formed by partial neutralization of an acid is called **acid salt** whereas a salt which is formed by the complete neutralization of an acid is called a **normal salt.**

Which salt is acid salt, $NaHCO_3 or\ Na_2CO_3$?

Which salt is normal salt, $NaHCO_3 or\ Na_2CO_3$?

Phosphoric acid (H_3PO_4) has three replaceable H-atoms, it forms three series of salts,$NaH_2PO_4, Na_2HPO_4, Na_3PO_4$. Which of these salts is/are acid salt?

A salt containing replaceable OH group or formed by the partial neutralization of a polyhydroxy base is called as basic salt.

$$\boldsymbol{Zn(OH)_{2(aq)} + HCl_{(aq)} \longrightarrow Zn(OH)Cl_{(aq)} + H_2O}$$

$$\boldsymbol{Pb(OH)_{2(aq)} + CH_3COOH_{(aq)} \longrightarrow Pb(OH)CH_3COO_{(aq)} + H_2O}$$

Self Assessment Exercise 10.7

Classify following salts as normal or acid salt.

(a) $NaHSO_4$
(b) Na_2SO_4
(c) $KHCO_3$
(d) K_2CO_3

Reading

10.3.1 Methods for making salt

There are five methods for making salts.

1. $\boldsymbol{Acid + Base \longrightarrow Salt + Water}$

$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

2. $\boldsymbol{Acid + Metal\ oxide \longrightarrow salt + water}$

$H_2SO_{4(aq)} + CuO_{(s)} \longrightarrow CuSO_{4(aq)} + H_2O_{(l)}$

3. $\boldsymbol{Acid + Metal \longrightarrow Salt + Hydrogen}$

$2HCl_{(aq)} + Mg_{(s)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$

4. $\boldsymbol{Acid + Metal\ carbonate \longrightarrow Salt + Carbon\ dioxide + water}$

$HCl_{(aq)} + CaCO_{3(s)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

5. $\boldsymbol{Salt_{(aq)} + Salt_{(aq)} \longrightarrow Salt_{(s)} + Salt_{(aq)}}$

$AgNO_{3(aq)} + NaCl_{(aq)} \longrightarrow AgCl_{(s)} + NaNO_{3(aq)}$

10.3 USES OF SALTS

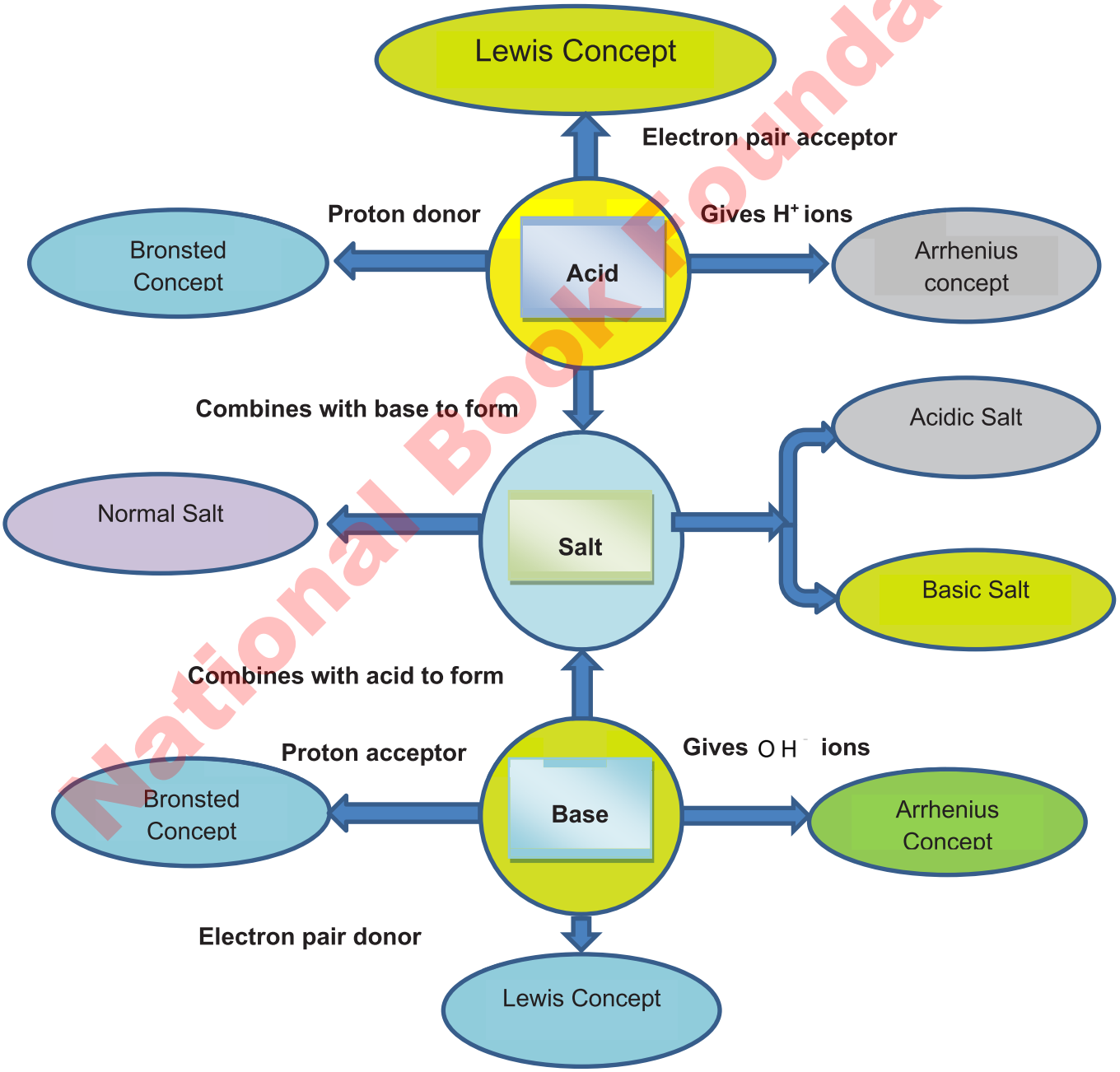
Food preservation keeps food from spoiling and allows it to be stored for later use. Ancient methods for preserving include, drying fruits and vegetables, salting, boiling etc. Today, methods for preserving food also include the addition of preservatives. They are inhibitors of physical and chemical processes that cause food to spoil. Many foods are grown or produced in one location and then sent across the country or even overseas. Without preservatives, these foods would spoil long before they reach their destinations. Many salts such as sulphites and benzoates are being used in food for thousands of years.

Society, Technology and Science

Preservatives in food are designed to prevent bacteria growth and spoilage. But sometimes they can affect your health. Some preservatives may cause breathing difficulties, can weaken heart tissues and can transform into carcinogens.

Many people are allergic or sensitive to preservatives. Some preservatives are safe in small amount and toxic in larger amounts. Hence, Food and Drug Administration Department is given the responsibility for approving the safety and use of preservatives. Government regulations restrict the quantity of preservatives in food.

Concepts in brief



Key Points

- ❖ According to Arrhenius theory, an acid is a substance that ionizes in water to produce H^+ ions and a base is a substance that ionizes in water to produce OH^- ions.
- ❖ A Bronsted-Lowry acid is a proton donor and a base is a proton acceptor.
- ❖ A Lewis acid is a substance that can accept a pair of electrons to form a coordinate covalent bond.
- ❖ A Lewis base is a substance that can donate a pair of electrons to form a coordinate covalent bond.
- ❖ The reaction in which two water molecules react to produce ions is called as self-ionization of water.
- ❖ Ionization constant for water is also called as the ion-product constant for water. Its value is $1 \times 10^{-14} at\ 25°C$.
- ❖ $If [H^+] = 1 \times 10^{-7} M$ solution is neutral
  - $If [H^+] > 1 \times 10^{-7} M$ solution is acidic
  - $If\ [H^+] < 1 \times 10^{-7} M$ solution is basic
- ❖ A pH of 7 indicates a neutral solution
- ❖ Acids have pH less than 7.
- ❖ Bases have pH greater than 7.
- ❖ Indicators change colour within a small pH range and indicate the pH of solution by the colour.
- ❖ Methyl orange, bromothymol blue and phenolpthalein are common acid-base indicators.
- ❖ Salt is an ionic compound formed when replaceable hydrogen atom in an acid is replaced by a metal atom.
- ❖ Reaction between an acid and a base is called neutralization reaction.
- ❖ Acid salts contain one or more replaceable H-atoms.
- ❖ Normal salts are formed by the complete neutralization of acids.

References for additional informations.

- ❖ Longman Chemistry for IGCSE.
- ❖ IGCSE Chemistry.
- ❖ Cambridge IGCSE, Chemistry.
- ❖ Theories of Acids and Base Chemi guide.

Review

1. Encircle the Correct answer

(i) Which of the following cannot be classified as Arrhenius acid?

(a) $\boldsymbol{HNO_3}$ (b) $\boldsymbol{H_2CO_3}$

(c) $\boldsymbol{CO_2}$ (d) $\boldsymbol{H_2SO_4}$

(ii) NH_3 cannot be classified as a base by

(a) Lewis theory (b) Bronsted -Lowry theory

(c) Arrhenius theory (d) All of these theories

(iii) Which of the following is a Lewis base?

(a) BF_3 (b) HCl

(c) $AlCl_3$ (d) F^-

(iv) Choose Lewis acid

(a) CN^- (b) NH_3

(c) H_2O (d) H^+

(v) A drain cleaner solution contains 1.0×10^{-8} M, OH^- concentration. This Solution is

(a) acidic (b) basic

(c) neutral (d) cannot be predicted

(vi) Milk of magnesia contains $\boldsymbol{Mg(OH)_2}$. It is used as antacid. It neutralizes excess stomach acid. Which salt is formed in this reaction?

(a) $\boldsymbol{MgSO_4}$ (b) $\boldsymbol{MgCO_3}$

(c) $\boldsymbol{MgCl_2}$ (d) MgO

(vii) Ammonia is a base, because it

(a) Ionizes in water to give OH^- ions (b) Contains OH group

(c) Can accept an election pair (d) Can accept proton

(viii) Consider the following reaction?

$$H_2O + HCl \rightleftharpoons H_3O^+ + Cl^-$$

Which species is an electron pair acceptor in this reaction?

(a) H_2O (b) HCl

(c) H_3O^+ (d) none

(ix) In the following reaction which species is donating an electron pair?

$$NH_3 + BF_3 \longrightarrow [H_3N - BF_3]$$

(a) H (b) B

(c) N (d) BF_3

(x) An aqueous solution of NaOH is used as a drain cleaner. If the concentration of OH^- ions in this solution is 1.0 x 10^{-5}M, the concentration of H^+ ions in it would be?

(a) $1.0 \times 10^{-5} M$ (b) $1.0 \times 10^{-7} M$

(c) $1.0 \times 10^{-9} M$ (d) $1.0 \times 10^{-14} M$

2. Give short answers?

(i) Write the equation for the self-ionization of water.

(ii) Define and give examples of Arrhenius acids.

(iii) Why H^+ ion acts as a Lewis acid?

(iv) Why NH_3 acts as Bronsted-Lowry base?

(v) Why BF_3 acts as Lewis acid?

3. Ammonium hydroxide and nitric acid react and produce ammonium nitrate and water. Write balanced chemical equation for this neutralization reaction.

4. Write balanced chemical equations for the following neutralization reactions.

(i) $Sulphuric\ acid + Magnesium\ hydroxide \longrightarrow magnesium\ sulphate + water.$

(ii) $Sulphuric\ acid + Sodium\ hydroxide \longrightarrow Soduimsulphate + water.$

(iii) $Hydrochloric\ acid + calcium\ hydroxide \longrightarrow calcium\ chloride + water$

5. Identify Bronsted –Lowry acids or bases in the following reactions.

(i) $HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$

(ii) $NH_3 + HNO_3 \longrightarrow NH_4NO_3$

6. Identify Lewis acid and Lewis base in the following reactions.

(i) $F^- + BF_3 \longrightarrow [BF_4]^-$

(ii) $H^+ + NH_3 \longrightarrow [NH_4]^+$

(iii) $NH_3 + AlCl_3 \longrightarrow [H_3N - AlCl_3]$

7. Classify the following solutions as acidic, basic or neutral.

(i) $A\ solution\ that\ has\ hydrogen\ ion\ concentration\ 1.0 \times 10^{-3} M.$

(ii) $A\ solution\ that\ has\ hydrogen\ ion\ concentration\ 1.0 \times 10^{-10} M.$

(iii) $A\ solution\ that\ has\ hydroxyl\ ion\ concentration\ 1.0 \times 10^{-3} M.$

(iv) $A\ solution\ that\ has\ hydroxyl\ ion\ concentration\ 1.0 \times 10^{-10} M.$

8. Classify following substance as Lewis acid and bases.

$NH_3,\quad F^-,\quad H_2O:\quad ,\quad BF_3$

9. Give the Bronsted-Lowry definition of an acid. Write an equation that illustrates the definition.

10. Identify Bronsted acids and Bronsted bases in the following reactions.

(i) $CH_3COOH_{(aq)} + H_2O \rightleftharpoons CH_3COO^-{}_{(aq)} + H_3O^+{}_{(aq)}$

(ii) $HCO_3^-{}_{(g)} + H_2O_{(l)} \rightleftharpoons CO_{3(aq)}^{-2} + H_3O^+_{(aq)}$

(iii) $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

(iv) $HCl_{(aq)} + HCO_3^-{}_{(aq)} \rightleftharpoons H_2CO_{3(aq)} + Cl^-{}_{(aq)}$

(v) $HS^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons S^{-2}{}_{(aq)} + H_3O^+{}_{(aq)}$

11. Identify the Lewis acids and the Lewis bases in the following reactions.

(i) $H^+{}_{(aq)} + CN^-{}_{(aq)} \longrightarrow HCN_{(aq)}$

(ii) $B(OH)_{3(s)} + OH^-{}_{(aq)} \longrightarrow B(OH)_4^-{}_{(aq)}$

(iii) $Cu^{+2}_{(aq)} + 4NH_{3(aq)} \longrightarrow [Cu(NH_3)_4]^{+2}_{(aq)}$

(iv) $OH^-_{(aq)} + Al(OH)_{3(s)} \longrightarrow Al(OH)^-_{4(aq)}$

12. Identify Lewis acids and Lewis bases from the following.

$AlCl_3$, Ag^+, $CH_3—\ddot{O}H$, $CH_3—\ddot{N}H_2$, $FeCl_3$

13. Classify water as proton donor or proton acceptor.

14. Write equations showing the ionization of the following as Arrhenius acids.

(a) $HI_{(aq)}$ (b) $HNO_{2(aq)}$

15. Write equations showing the ionization of the following as Bronsted-Lowry acids.

(a) $HNO_{2(aq)}$ (b) $HCN_{(aq)}$

Think-Tank

16. Compare the relative concentrations of hydrogen ions and hydroxide ions in each kind of solution?

(a) acidic (b) basic (c) neutral

17. Codeine, $C_{18}H_{21}NO_3$ is a commonly prescribed pain killer. It dissolves in water by the following reaction?

$$C_{18}H_{21}NO_3 + H_2O \rightleftharpoons [C_{18}H_{21}HNO_3]^+ + OH^-$$

Differentiate Codeine and water as Bronsted-Lowry acid or base.

18. Examine some ways in which you might determine whether a particular water solution contains an acid or a base.

19. The table below shows the colours of two indicators in acidic and alkaline solutions.

Indicator	Colour in Acidic Solution	Colour in Alkaline Solution
A	Red	Blue
B	Colourless	Red

a) Predict the colour of the indicator A?

i. in a solution of pH 3

ii. in a solution of pH 10

b) Predict the colour of the indicator B in a solution of pH 5?

c) When a few drops of indicator B are placed in a solution X, it turns red immediately. Evaluate the properties of solution X?

20. Bacteria in our mouth feed on small particles of food stuck to our teeth and change it into acid. A toothpaste of pH 10 can help to prevent the acid from damaging our teeth. Defend the statement.

21. Can a substance be a Lewis acid without being a Bronsted-Lowry acid? Argue.

Project

Examine the labels of at least three antacid preparations. Make a list of the ingredients in each. Write a balanced chemical equation for the neutralization reaction that takes place when these antacids react with HCl in the stomach.

11

ORGANIC CHEMISTRY

After completing this lesson, you will be able to:

This is 13 days lesson (period including homework)

- Recognize structural, condensed and molecular formulas of the straight chain hydrocarbons up to ten carbon atoms.
- Identify some general characteristics of organic compounds.
- Explain the diversity and magnitude of organic compounds.
- List some sources of organic compounds.
- List the uses of organic compounds.
- Recognize and identify molecule's functional groups.
- Distinguish between saturated and unsaturated hydrocarbons.
- Name the alkanes up to decane.
- Convert alkanes into alkyl radicals.
- Differentiate between alkane and alkyl radicals.
- Define functional group.
- Differentiate between organic compounds on the basis of their functional groups.
- Classify organic compounds into straight chain, branched chain and cyclic compounds.
- Identify carboxylic acids, phenols, amines, aldehydes and ketones in terms of functional groups in the lab.
- Distinguish between saturated and unsaturated compounds using iodine, bromine and potassium permanganate solutions.
- Show how pharmaceutical chemists work towards the partial and total synthesis of effective new drugs.
- Explain how substances produced by plants and animals can also be produced in the lab.

Reading

INTRODUCTION:

The Study of Carbon containing compounds and their properties is called organic chemistry. However, few compounds of carbon such as carbon dioxide, carbon monoxide, carbonates and carbides are considered to be inorganic substances. This is

because they have totally different properties than organic compounds. Organic compounds play a vital role in the bodies of living things. Products of industrial organic chemistry such as plastics, rubber, synthetic fibers, paints, glues, varnishes, artificial sweeteners and flavors, drugs, dyes, soaps and detergents etc. are important part of modern life. In addition, the energy on which we rely heavily is based mostly on organic materials found in coal, petroleum and natural gas.

11.1. ORGANIC COMPOUNDS

The Chemistry of carbon compounds pervades every aspect of our lives. We use thousands of carbon compounds every day. They are carrying out important chemical reactions within our bodies. Many of them are so vital that we cannot live without them. A detailed study of organic compounds confirms that carbon is their essential constituent in combination with H, O, N, S, P and halogens. They may also (rarely) contain metal atoms. **Organic compounds are defined as the hydrocarbons and their derivatives. (see sction 11.4 and Chapter 12)**

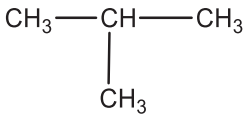
11.1.1 Chemical Diversity and Magnitude of Organic Compounds

Carbon has four bonding electrons in its valence shell. Carbon therefore forms four bonds with other atoms.

The Chemical diversity of organic compounds arises from carbon's ability to bond to each other to form long chains, branched chains and rings. This self-linking ability of carbon is called **catenation.** There appears to be almost no limit to the number of different structures that carbon can form. (See 11.1.6). No other element can compete with carbon in this regard. Silicon and few other elements can form chains, but only short one. Carbon chains may contain thousands of carbon atoms. For these reasons carbon forms almost infinite number of molecules of various sizes, shapes and structures. Another reason for the large number of organic compounds is the phenomenon of **isomerism.**

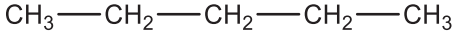
The compounds that have same molecular formula but different arrangement of atoms in their molecules are called isomers. This phenomenon is called isomerism. For example two compounds have molecular formula C_4H_{10}

n – Butane

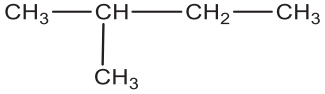


iso – Butane

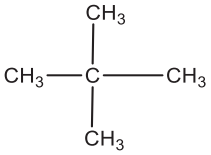
What is the molecular formula of the following compounds?



n – Pentane



iso – Pentane



neo - Pentane

Teacher's Point

A teacher may give examples of petrol, kerosene, diesel, mobile oil as hydrocarbons.

This means three compounds have molecular formula C_5H_{12}.As the number of carbon atoms in an organic compound increases, the number of possible isomers also increase. What is the number of isomers in pentane? Hexane has five isomers.

Carbon can also form stable single and multiple bonds with other atoms like oxygen, nitrogen and sulphur.

Carbon can also make **multiple bonds** to itself i.e. $C{=}C$, $C{\equiv}C$, $C{=}O$, $C{\equiv}N$ etc. This further increase the number of organic compounds. In fact, many common groups of atoms can occur within organic molecules. These groups are called functional group. (See 11.4). That is why of more than 20 million known chemical compounds; over 95% are compounds of carbon. Millions of organic compounds are already known and new ones are being discovered every day.

In fact many common groups of atoms can occur within organic molecules. These groups are called functional groups. (See 11.5).

11.1.2 General Characteristics of Organic Compounds

(i) Occurrence:

Most of them come from living things or from the things that were once living.

(ii) Covalent nature:

Organic compounds are generally covalent in nature. They may have polar or non-polar bonds.

(ii) Composition:

Carbon is the main constituent of organic compounds. Hydrogen is also frequently present in organic compounds. Other elements like oxygen, nitrogen, sulphur, phosphorous and halogens are present in many organic compounds.

(iv) Melting and boiling point:

Generally organic compounds are volatile. So they have low melting and boiling points.

(v) Solubility:

Organic compounds are mostly non-polar in nature therefore they are soluble in organic solvents such as ether, benzene, carbon disulphide etc. Polar Organic Compounds are soluble in alcohols such as methyl alcohol and ethyl alcohol.

(vi) Similarity in behaviors (Homology):

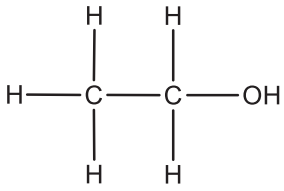
There exists a close relationship between different organic compounds. This similarity in behavior has made the study of millions of organic compounds easier. They can be classified into few families. A series of related compounds in which any two adjacent molecules differ by $–CH_2–$ group is called homologous series.

(vii) Reaction rates:

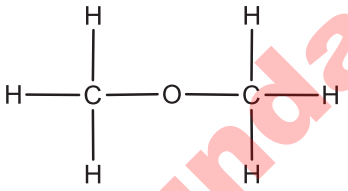
Organic compounds are generally less stable than inorganic compounds. Due to covalent bonding in them, their reaction rates are often slow.

11.1.3 Condensed Structural Formulas

Frequently more than one organic compounds are represented by the same molecular formula. However, they have different properties. They have different structural formulas. For example, two organic compounds have the molecular formula C_2H_6O. they have different arrangements of atoms.



Ethanol

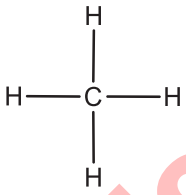


Dimethy ether

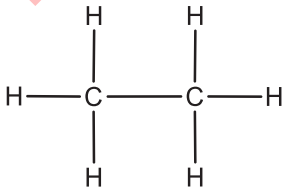
These formulas clearly show that the atoms are bonded to one another differently. In ethanol, the oxygen atom is bonded to only one carbon atom and a hydrogen atom. Whereas in dimethyl ether, the oxygen atom is bonded to two carbon atoms.

A formula that describes the arrangement of atoms in a molecule is called as structural formula.

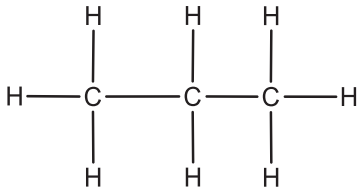
The simple alkanes are straight-chain hydrocarbons. First three members of alkanes have following structural formulas.



Methane



Ethane



Propane

The condensed structural formulas of these alkanes are

$$CH_4 \quad , \quad CH_3CH_3 \quad , \quad CH_3CH_2CH_3$$

The corresponding molecular formulas are CH_4, C_2H_6, C_3H_8 respectively

A condensed formula is a structural formula that uses established abbreviation for various groups of chain. In condensed structural formula, we list the main chain carbon atoms and the hydrogen atoms attached to them in the sequence in which they appear in the naming system.

For instance,

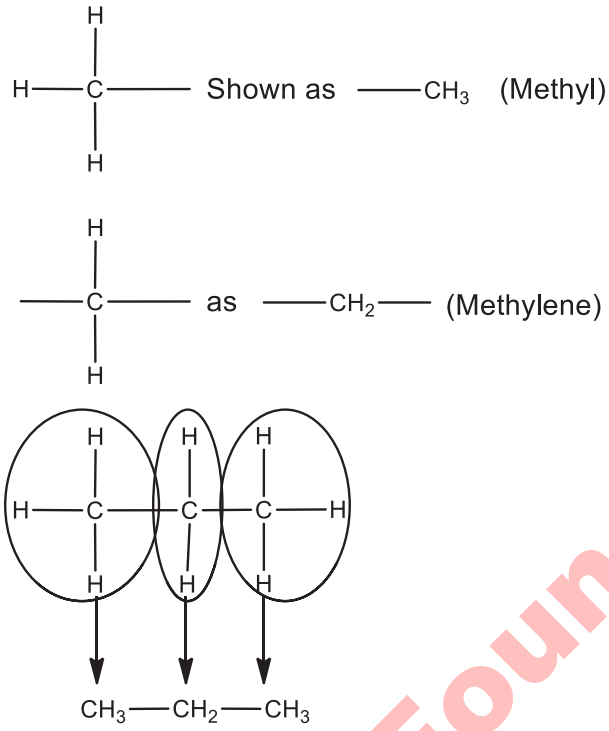


Table **11.1** shows the condensed structural formulas of some alkanes.

Table 11.1 Condensed structural formula of some alkanes

Name	Molecular Formula	Condensed Formula
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$
Hexane	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$
Heptane	C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$
Octane	C_8H_{18}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
Nonane	C_9H_{20}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$
Decane	$C_{10}H_{22}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

Example 11.1: Give the molecular formula, the structural formula and the condensed structural formula for pentane.

Problem Solving Strategy

i) The stem pent –means five carbon atoms.

ii) The ending -ane indicates an alkane.

iii) Write a string or chain of five carbon atoms.

iv) Attach hydrogen atoms to the carbons to give each carbon atom four bonds. This requires three hydrogen atoms on each end carbon and two each on others.

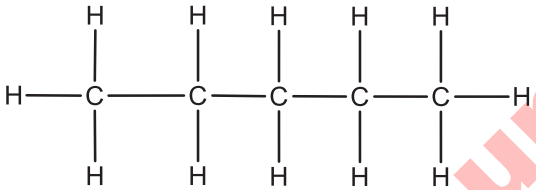
v) For the condensed molecular formula, write each carbon atom's set of hydrogen atoms next to the carbon.

vi) For molecular formula, simply count the carbon and hydrogen atoms or use the general formula $C_nH_{2n+2}$with n=5.

Solution:

C - C - C - C -C

Structural formula



Condensed Structural formula

$CH_3—CH_2—CH_2—CH_2—CH_3$

Molecular formula

$$C_5H_{2x5+2} = C_5H_{12}$$

Self-Assessment Exercise 11.1

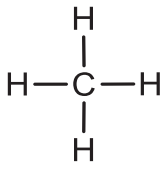
Give the molecular, structural and condensed structural formulas for

(a) Butane (b) Hexane (c) Octane

Reading

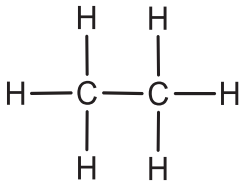
11.1.4 Saturated and Unsaturated Hydrocarbons

Hydrocarbons are compounds containing carbon and hydrogen only. **Hydrocarbons whose carbon – carbon bonds are all single bonds are called saturated.** Saturated hydrocarbons are also called alkanes. In alkanes each carbon atom is bonded to four other atoms. Methane is the simplest alkane. Other examples are ethane, propane, butane etc. (**See section 11.1.3** for more examples). The general formula of alkanes isC_nH_{2n+2}, where n is the number of carbon atoms.

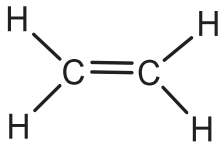


Methane

Hydrocarbons containing carbon-carbon multiple bonds are called unsaturated. Which of the following are unsaturated hydrocarbons?



Ethane



Ethene

Ethyne

Unsaturated hydrocarbons are further divided into:

(i) **Alkenes.**

(ii) **Alkynes.**

Unsaturated hydrocarbons containing at least one carbon-carbon double bond are called alkenes. They have general formula (H_2SO_4), for example ethene. Unsaturated hydrocarbons that have at least one carbon-carbon triple bond are called alkynes. They have general formula C_nH_{2n-2}, for example ethyne.

Self-Assessment Exercise 11.2

Choose saturated and unsaturated compounds from the following.

(i) $CH_3-CH_2-CH_3$ (ii) $CH_3-C\equiv CH$

(ii) $CH_3-CH=CH_2$ (iv) $CH_2=CH-CH=CH_2$

Reading

11.1.5. Naming Alkanes

An international body, the international union of pure and applied chemistry (IUPAC) has devised a system of naming organic compounds that depends on their structure. These names

indicate the number of carbon atoms present in the organic compounds. We can easily recognize organic compound by its IUPAC name. Such names are also called systematic names.

The key point in naming a straight chain alkane is that the name is based on the number of carbon atoms in the chain. The IUPAC name has two parts.

(i) Stem:

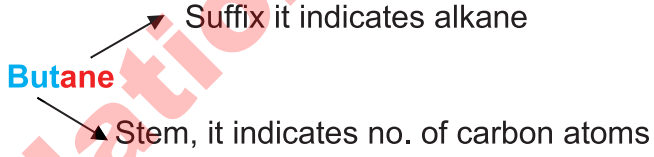
The stem tells the number of carbon atoms in the chain. Table 11.2 shows these stems.

Table 11.2: Numerical stems for carbon chains

Stem	Number of C - atoms
Meth-	1
Eth-	2
Prop-	3
But-	4
Pent-	5
Hex-	6
Hept-	7
Oct-	8
Non-	9
Dec-	10

(ii) Suffix:

Suffix is placed after the stem, it tells the class of compound. For alkane, the suffix “ane” is used.



Example 11.2: Writing names of alkanes

Write IUPAC names of the following compounds.

(i) $\boldsymbol{CH_3 - CH_2 - CH_2 - CH_3}$ **(ii)** $CH_3 - CH_2 - CH_2 - CH_2 - CH_3$

Problem solving strategy

(i) Count number of carbon atoms in the chain and select stem for it.

(ii) Add suffix – ane to the stem.

Solution

(i) No. of Carbon atoms 4

Stem ⟶ But

Name: Butane

(ii) No. of Carbon atoms 5

Stem ⟶ Pent

Name: Pentane

Self-Assessment Exercise 11.3

Write IUPAC names of the following alkanes.

(i) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_3$

(ii) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_3$

(iii) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_3$

(iv) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_3$

(v) $CH_3- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_2- CH_3$

Reading

11.2 SOURCES OF ORGANIC COMPOUNDS

The major commercial sources of alkanes are coal, natural gas, petroleum, and living organisms.

Coal

Coal is a source of many organic compounds. When coal is heated in the absence of air at high temperature, it is converted into coal gas, coal tar and coke. This process is called destructive distillation. Coal is also used as solid fuel.

Coal gas contains methane, hydrogen and carbon monoxide gases. It is mainly used as a fuel in industry. Coal tar is a source of many organic compounds such as benzene and its derivatives. These compounds can be separated by fractional distillation. These are very useful substances in synthetic organic chemistry. These are used to synthesize plastics, dyes, fibers, drugs, paints, varnishes etc. The residue left behind called pitch is used to metal roads and roofs.

Natural gas

Natural gas is a mixture of low boiling hydrocarbons. Natural gas is mostly methane. It also contains smaller amounts of ethane, propane and butane.

Petroleum

Petroleum contains a wide variety of alkanes including those having very long chains. On fractional distillation petroleum separates into various hydrocarbon components, known as fractions. Can you name these fractions? Each fraction is not a pure compound but a mixture of different compounds that boil in a certain range of temperature. (See section 16.4)

Living Organisms

Many important organic compounds such as proteins, fats, carbohydrates, vitamins, drugs and medicines are obtained from plants and animals.

Synthesis in Laboratory:

Over ten million organic compounds have been prepared in the laboratories. They are being used in medicines, cosmetics, paints, plastics, fertilizer, detergents, etc.

11.3 USES OF ORGANIC COMPOUNDS.

- Natural gas and petroleum are used primarily as fuels (see figure 16.9). These are also used as starting materials for the productions of variety of organic compounds.
- Propane and butane which are gases obtained from natural gas are widely available as liquids in fuel cylinders (LPG).
- Ethylene is the major starting material for the manufacture of organic chemicals and products such as polyethylene (plastic), ethyl alcohol, acetic acid and ethylene glycol called antifreeze.
- Acetylene is widely used in the oxy-acetylene welding and cutting metals. Acetylene is also used in the preparation of polymers like PVC (polyvinyl chloride), polyvinyl acetate, synthetic rubber, nylon etc.
- Acetylene is used for artificial ripening of fruits.
- Compounds of phenol help to ensure antiseptic conditions in hospital operating rooms.
- Methanol is used as a solvent for fats, oils, paints and varnishes.
- Many organic compounds are used in the manufacturing of drugs, dyes, cosmetics, detergents and soaps, nylon, emulsions and paints etc.

Self-Assessment Exercise 11.4

1. List the names of major sources of alkanes.
2. What is natural gas?
3. Write some uses of acetylene.

Teacher's Point

Teacher may show different organic compounds to students.

Reading

11.4. ALKANE AND ALKYL RADICALS

Recall that an alkane is a hydrocarbon containing only single bonds and have general formula C_nH_{2n+2}.

An alkyl radical is a group of atoms obtained by removing one hydrogen atom from an alkane. Alkyl radicals are represented by the symbol R.

Example 11.3 Converting alkanes into alkyl radicals

Convert following alkanes into alkyl radical.

(i) Methane **(ii)** Ethane

Problem Solving Strategy

(i) Write condensed structure formula for the given compound.

(ii) Remove a hydrogen atom from the terminal carbon atom.

(iii) Write name of the radical by removing ending -ane of alkane by -yl

Solution

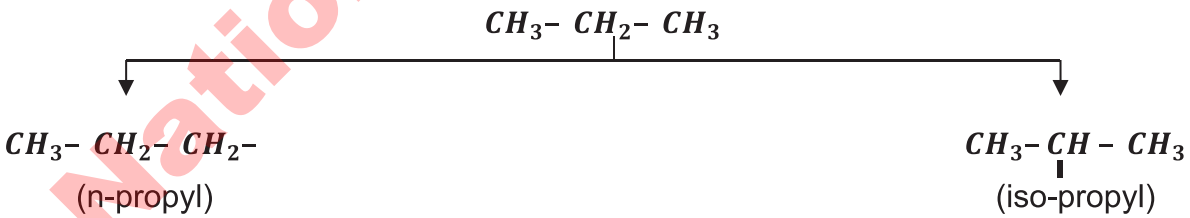
(i) CH_4 CH_3-

Methane **Methyl**

(ii) CH_3CH_3 CH_3CH_2-

Ethane **Ethyl**

What is the difference between methane and methyl radical? Which one contain a free valency? Alkanes containing more than two carbon atoms form more than one alkyl groups. For instance, propane forms two alkyl groups or radicals. The group obtained by removing terminal hydrogen atom is called n-propyl and that obtained by removing H-atom from central carbon atom is called iso-propyl group.



Self-Assessment Exercise 11.5

Derive alkyl radicals from the following alkanes.

a. Ethane b. Butane c. Propane

Reading

11.1.6. Classification of Organic Compounds

There are millions of organic compounds. It is not possible to study each compound individually. To make the study easy, they are classified into various groups and sub-groups. It is helpful to pick out these compounds which have similar structure. So you will learn here, the classification of organic compounds on the basis of carbon skeleton. They are broadly classified into two main groups.

Do you know?

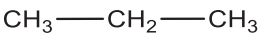
Alkyl radical contains one less hydrogen than its parent alkane.

(i) Open chain compounds or Acyclic compounds.

(ii) Closed chain or Cyclic Compounds.

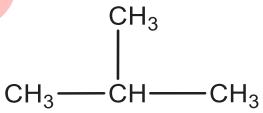
(i) Open chain compounds.

Open chain compounds contain an open chain of carbon atoms. For instance

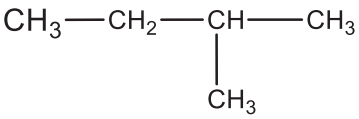


Propane

Butane

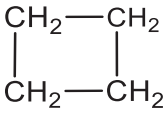


iso-Butane



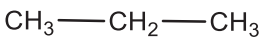
iso – Pentane

Is the compound having following structure an open chain compound?



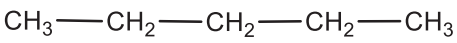
Open chain compounds may be either straight-chain or branched-chain. Those compounds which contain any number of carbon atoms joined one after the other in a chain or row are called **straight – chain compounds.**

For example



Propane

Butane

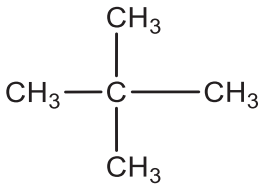


Pentane

Teacher's Point

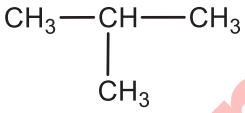
Teacher may tell students that Sui Gas is mainly methane containing small amount of ethane, propane and butane.

Those compounds which contain carbon atoms on the sides of chain are called branched chain compounds. Which of the following is a branched chain compound?



neo-Pentae

Butane

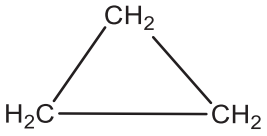


iso-Butane

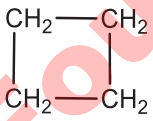
Open chain compound are also called alicyclic compounds

(ii) Closed Chain or Cyclic Compounds

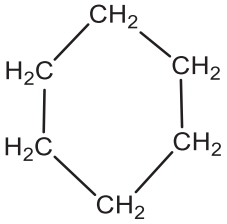
Organic compounds which contain rings of atoms are called closed chain or cyclic compounds. For example



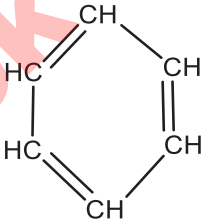
Cyclopropane



Cyclobutane



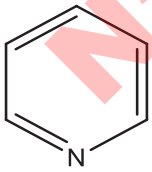
Cyclo hexane



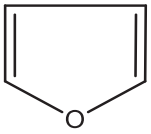
Benzene

or

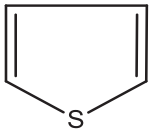
Cyclic compounds which contain rings of carbon atoms are called homocyclic or carbocyclic compounds. Which of the above cyclic compounds are carbocyclic? Cyclic compounds that contain one or more atoms other than carbon atoms in the ring are called heterocyclic compounds e.g.



Pyridine



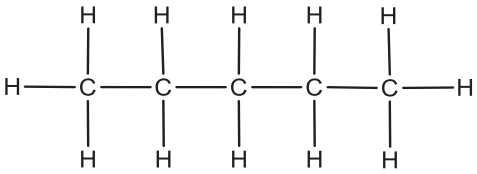
Furan



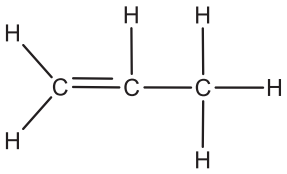
Thiophene

Self-Assessment Exercise 11.6

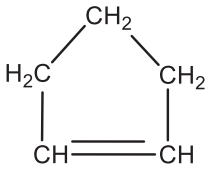
A to E are the structural formulas of some organic compounds.



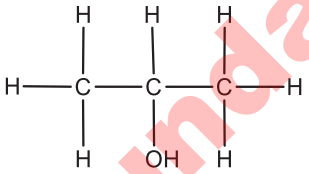
A



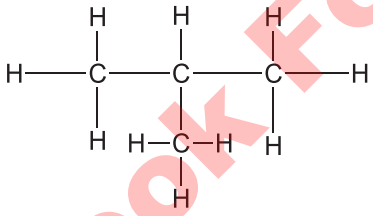
B



C



D



E

Give the letters which represents

(i) A branched chain compound.

(ii) A cyclic compound.

(iii) Two straight chain compounds.

Reading

11.4 FUNCTIONAL GROUPS

The vast majority of organic compounds contain elements in addition to carbon and hydrogen. Most of these compounds are considered as derivatives of hydrocarbons. This means that they are basically hydrocarbons but they have additional atom or groups of atoms in place of one or more hydrogen atoms called functional groups. In many simple molecules, a functional group is attached to an alkyl group.

An atom or groups of atoms that give a family of organic compounds its characteristic chemical and physical properties is called a functional group.

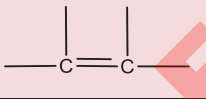
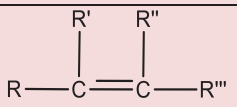
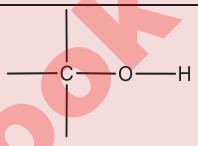
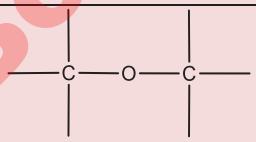
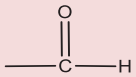
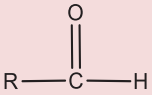
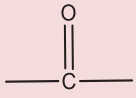
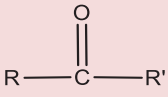
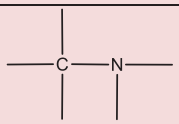
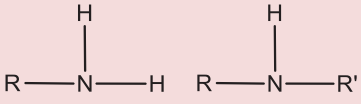
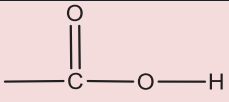
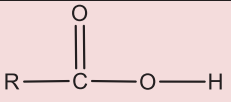
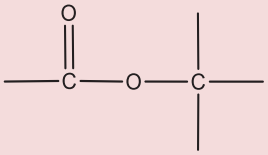
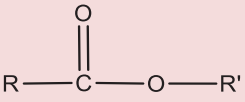
What is the difference in the following compounds?

CH_4	$H_3C—OH$	$H_3C—Cl$
Methane	Methyl alcohol	Methyl Chloride

The common functional groups are listed in the table 11.2.

The study of organic chemistry is organized around functional groups. Each functional group defines a family of organic compounds. Although, there are millions of organic compounds, yet there are only a handful of functional groups. So functional groups make the study of millions of organic compounds easier.

Table 11.2: Some Common Functional groups

Name of class	Functional group	General formula
Alkane	None	R—H
Alkane		
Alkyne		
ALcohol		
Ether		
Aldehyde		
Ketone		
Amine		
Carboxylic acid		
Ester		

Each functional group exhibits character

11.5.1 Functional groups containing Carbon, Hydrogen and Halogens: Haloalkanes

Haloalkanes are characterized by the presence of the halogen atom. The haloalkane is compound in which one hydrogen atom of an alkane is substituted by one halogen atom. Which of the following molecules are haloalkanes?

CH_4	$H_3C—Cl$	$H_3C—Br$	CH_3CH_3	$CH_3CH_2—Cl$
Methane	Chloromethane	Bromomethane	Ethane	Chloroethane

11.5.2 Functional groups containing Carbon, Hydrogen and Oxygen: Alcohols

Alcohols are characterized by the presence of the hydroxyl group. (-OH) attached to a hydrocarbon chain.

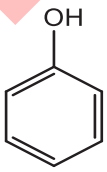
$H_3C—OH$	$CH_3CH_2—OH$
Methanol (Methyl alcohol)	Ethanol (Ethyl alcohol)

R – OH is the general formula for alcohols. Which of the following compounds is alcohol?

$CH_3CH_2CH_2OH$	$CH_3CH_2CH_2CH_2OH$
1-Propanol	1-Butanol

Phenols

When an – OH group is attached to a benzene ring, the compound is called a phenol.



or $C_6H_5—OH$

Phenol

Phenol was the first antiseptic used in an operation theatre.

Ethers

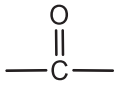
Organic compounds that have two alkyl groups attached to the same oxygen atom are called ethers. These compounds have C–O–C linkage in their molecules.

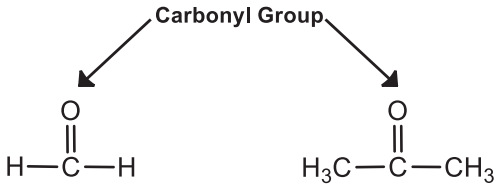
$CH_3—O—CH_3$	$CH_3—O—CH_2—CH_3$	$CH_3—CH_2—O—CH_2—CH_3$
Dimethyl ether	Ethyl methyl ether	Diethyl ether

The general formula for ethers is R-O-R/. Where R and R/ are alkyl groups which may be same or different.

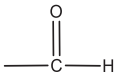
Aldehydes and ketones

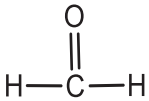
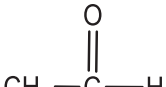
Aldehydes and ketones contain the carbonyl group


or —CO—

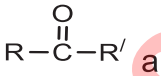


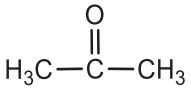
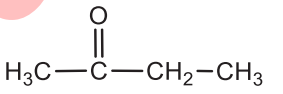
An aldehyde has at least one hydrogen atom or two hydrogen atoms attached to the carbonyl carbon atom. A ketone has two hydrocarbon groups (alkyl) bonded to the carbonyl carbon atom. Which of the above compound is an aldehyde? Which is a ketone?

 group in condensed form is written as –CHO. It is characteristic group of aldehydes.

HCHO or  CH_3CHO or 

Methanal (Formaldehyde) Ethanal (Acetaldehyde)

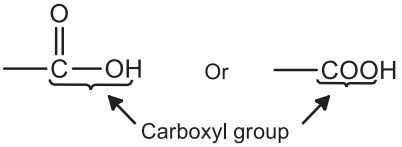
The general formula for ketone is  and in condensed form it is written as $RCOR^{/}$. Where R and $R^{/}$ are alkyl groups which may be same or different. For example

 or CH_3COCH_3  or $CH_3COCH_2CH_3$

Propanone (Acetone) Butanone

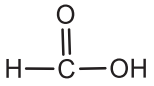
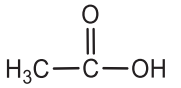
Carboxylic Acids:

The functional group of organic acid is called the carboxyl group.



What is the difference between a carbonyl group and a carboxyl groups?

Examples:

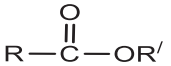
 or HCOOH  or CH_3COOH

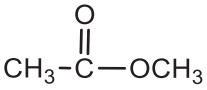
(Formic acid) Methanoic acid (Acetic acid) Ethanoic acid

The general formula for carboxylic acids is R – COOH

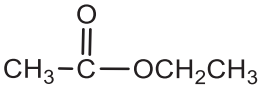
Where R = H or alkyl group

Esters:

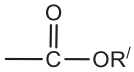
Compounds having general formula  are called esters. R and R/ are alkyl groups which maybe same or different.



(Methyl acetate) Methyl ethanoate



(Ethyl acetate) Ethyl ethanoate

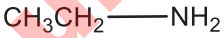
 is the functional group for esters.

11.5.3 Functional groups containing Carbon, Hydrogen and Nitrogen

Amines

The functional group of amines is – NH_2

Methyl amine



Ethyl amine

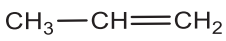
The general formula for amines is $R-NH_2$

11.5.4 Functional groups containing Double and Triple bond

An alkene is a hydrocarbon that contains one or more carbon-carbon double bond. -C=C- is the functional group for alkenes. An alkyne is a hydrocarbon that contains one or more carbon-carbon triple bond. -C≡C- is the functional group for alkynes. Which of the following compound is alkene, which is alkyne?

(II)

(II)



(III)

Example11.4: Differentiating different organic compounds on the basis of their functional groups.

Classify the following compounds as an alcohol, ether or a phenol.

(a) $CH_3CH_2OCH_2CH_3$, is an anesthetic, but its' use as an anesthetic is now limited. This is because it is inflammable and causes nausea.

(b) C_6H_5OH is a strong germicide. It is commonly used as disinfectant for floors, furniture and washrooms.

(c) CH_3OH is poisonous and can cause blindness or death if taken internally.

Problem Solving Strategy:

(i) Identify alkyl group in the molecule and functional group.

(ii) When –OH group is attached to an alkyl group, the compound is an alcohol, but when –OH is attached to benzene ring, the compound is a phenol.

(iii) When O– atom is attached to two alkyl groups, the compound is an ether.

Solution

(a) Ether (b) Phenol (c) Alcohol

Self-Assessment Exercise 11.7

Classify the following compound as alcohol, ether or phenol.

(a) $CH_3CH_2OCH_2CH_3$ (b) $CH_3CH_2CH_2OH$

(c) C_6H_5OH (d) C_2H_5OH

Reading

Example 11.5: Classify the following organic compounds on the basis of functional group.

Identify the following compounds as an aldehyde or a ketone or a carboxylic acid.

(a) $CH_3COCH_3$is a common solvent for organic materials such as fats, rubbers, plastic and varnishes.

(b) CH_3CH_2CHOhas a foul irritating odour.

(c) $CH_3COOH$is present in vinegar and is used to flavor food and making a polymer called polyvinyl acetate.

Problem Solving Strategy

Remember that

(i) In an aldehyde a hydrogen atom is attached to the carbonyl carbon atom.

(ii) In a carboxylic acid –OH group is attached to the carbonyl carbon atom.

(iii) In a ketone, the carbonyl carbon is between two other carbon atoms.

Solution

(a) A ketone (b) An aldehyde (c) An organic acid

Self-Assessment Exercise 11.8

Identify the following compounds as an aldehyde, or a ketone or a carboxylic acid.

(a) $CH_3COCH_2CH_3$ (b) $CH_3CH_2\overset{\overset{O}{\|}}{C}H$ (c) $CH_3CH_2\overset{\overset{O}{\|}}{C}OH$

Almost all synthesis involve the inter conversion of at least one functional group to another. A functional group is the active portion of the molecule. It plays a key role in the

synthesis of new compounds. The key to design most organic synthesis is the functional group in the target molecules.

SKILLS

Society, Technology and Science

Pharmaceutical chemists seek ideas for new drugs not only from plants but also from any part of animals. They isolate the active ingredients for drug material methods include cold maceration and methanolic or ethanolic extraction. Then, they test drug on animals and perform, other clinical tests. After successful tests, pharmacists develop a manufacturing process for new effective drug in a laboratory. They use computer-aided software for drug design.

To develop a synthesis scheme for a particular substance produced by plants and animals or new effective drug, pharmaceutical chemists first analyze the target molecule. They look for a suitable starting material. The synthesis involves two steps.

(i) Changes in the carbon skeleton

(ii) Inter conversion of functional groups.

So, pharmaceutical chemists determine whether the reaction changes the carbon skeleton or inter converts the functional groups. If both the molecules have the same number of carbon atoms, then they can accomplish the synthesis by one or more functional group inter-conversion. If they are of different sizes, then they modify the carbon skeleton. For this they look for a molecule that allows them to make a possible carbon containing skeleton to obtain the product. Then they look for ways to obtain the functional groups of the target molecule.

Activity 11.1

Differentiate between saturated and un-saturated compounds using, iodine bromine and potassium permanganate.

Carry out the following:

- Dissolve 2-3 cm^3 of mustard oil in 5 cm^3 of carbon tetrachloride. Divide this solution into three parts.
- To one part add few drops of bromine water and shake. What happens?
- To the second part add few drops of iodine solution and shake. What happens?
- To the third part add few drops of dilute alkaline $KMnO_4$solution and shake (Baeyer's test). What happens?
- Repeat these steps with kerosene oil. What do you observe?

Un-Saturated Compounds Discharge

i) Reddish brown colour of bromine water.

ii) Purple colour of iodine solution

iii) Purple colour of alkaline $KMnO_4$

Saturated compounds do not give these tests.

Activity 11.2

Identifying carboxylic acids, phenols, amines, aldehydes and ketones in terms of functional groups.

Perform this activity in chemistry laboratory

Carry out the following:

i) Test for carboxylic acids

- Take 5 cm^3 of vinegar in a test tube and a pinch of $NaHCO_3$, test the gas evolved with lime water: what happens?
- Dip blue litmus paper in vinegar. What happens? These two tests indicate the presence of carboxylic group in vinegar.

ii) Test for phenol

- Dissolve a pinch of carbolic acid (phenol) in 5 cm^3 of water in a test tube.
- Add bromine water in the above solution.
- What happens? Phenol gives white ppt with bromine water.

iii) Test for amine

- Heat pinch of an amine in 2 cm^3 of alcoholic solution of KOH and 0.5 cm^3 of chloroform.
- Note the odour of fumes given out.

An amine gives extremely unpleasant or foul odour.

iv) Test for Aldehyde

- Mix equal volumes of Fehling's solution A and B in a test tube.
- Add a pinch of glucose init and boil for some time.
- What happens?

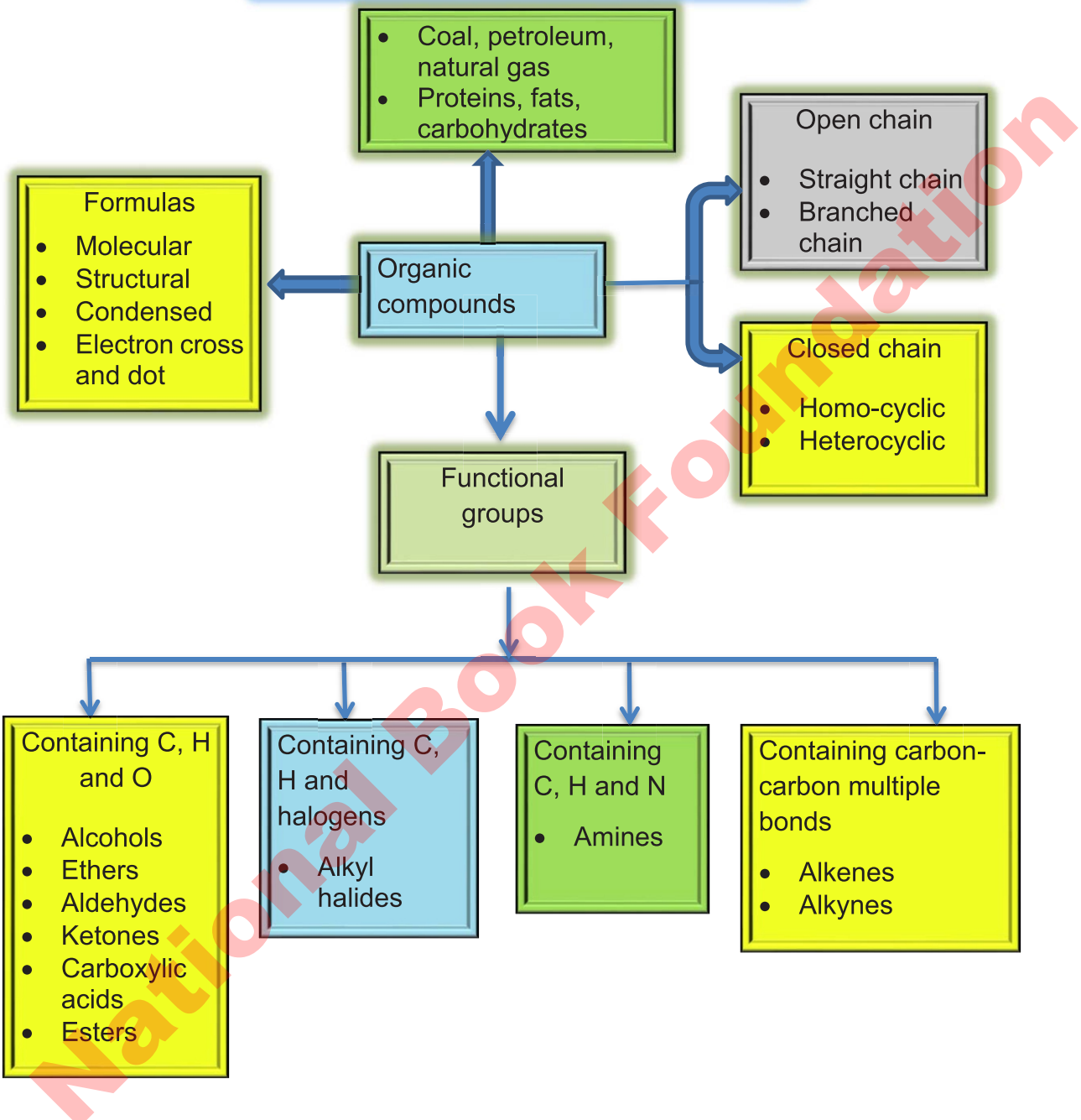
Aldehydes give red precipitate with Fehling's solution.

v) Test for ketone

- Take 2-3 cm^3 of sodium nitro-prusside solution in a test tube and few drops of NaOH solution.
- Add one cm^3 of acetone in the above test tube.
- What happens?

Ketones give red colour with alkaline sodium nitro-prusside solution.

Concepts in brief



Key Points

- The study of hydrocarbons and their derivatives is called organic chemistry.
- The self-linking ability of carbon atoms is called catenation.
- Structural formula describes the arrangement of atoms in a molecule.
- Condensed structural formula shows abbreviations for various group of chain.
- Hydrocarbons whose carbon-carbon bonds are all single bonds are called saturated hydrocarbons
- Hydrocarbons containing carbon-carbon multiple bonds are called unsaturated hydrocarbons.
- The stem is the part of the name of an organic compound that tells the number of carbon atoms in the chain.
- The suffix in the name of the compound tells the class of compound.
- Heating the coal in the absence of air at high temperature is called destructive distillation.
- Destructive distillation of coal gives coal gas, coal tar and coke.
- Fractional distillation of petroleum gives various hydrocarbon components known as fractions.
- An alkyl radical is a group of atoms obtained by removing one hydrogen atom from an alkane.
- Open chain compounds contain an open chain of carbon atoms.
- Straight chain compounds contain carbon atoms joined one after the other in a chain.
- Branched chain compounds contain carbon atoms on the side of chain.
- Cyclic compounds contain rings of carbon atoms.
- An atom or a group of atoms that give a family of organic compounds, its characteristics properties, is called a functional group.

References for additional information.

- Chemistry for changing times, John W. Hill, Doris K. Kolb.
- Longman chemistry for IGCSE, Jin Clark and Ray Oliver.

Review Question

1. Encircle the correct answer.

(i) Condensed structural formula for butane is

(a) $CH_3- CH_2- CH_3$ (b) $CH_3- CH_2- CH_2- CH_3$

(c) $CH_3- CH_2- CH_2- CH_2- CH_3$ (d) $CH_3- CH_3$

(ii) $CH_3- CH_2- CH_3$ is the chemical formula for

(a) Ethane (b) Propane (c) Butane (d) Pentane

(iii) Which compound is not a saturated hydrocarbon?

(a) $CH_3—CH_3$ (b) CH_4

(c) $CH_3—CH=CH_2$ (d) $CH_3—CH_2—CH_3$

(iv) Stem "But" stands for how many Carbon atoms.

(a) 2 (b) 3 (c) 4 (d) 5

(V) Pitch is produced by

(a) Coal (b) Coal tar (c) Coal gas (d) Petroleum

(vi) The functional group $—\overset{\overset{O}{\|}}{C}—$ is found in

(a) Alcohols (b) Ketones (c) Carboxylic acids (d) Esters

(vii) In which of the following Compounds, oxygen is attached to two alkyl carbon atoms?

(a) Alcohol (b) Phenol (c) Ether (d) Ester

(viii) Which of the following is an alcohol?

(a) $CH_3- CH_2- O- CH_2- CH_3$ (b) $CH_3- CH_2- COOH$

(c) $C_6H_5- OH$ (d) $CH_3- CH_2- OH$

(ix) The functional group of amines is

(a) –OH (b) – COOH (c) – NH_2 (d) – CHO

(x) Formic acid contains functional group

(a) – OH (b) – CO – (c) –COOH (d) – CHO

2. Give short answer.

(i) What is catenation?

(ii) Define isomerism.

(iii) Give three examples of alkyl groups.

(iv) Define a functional group.

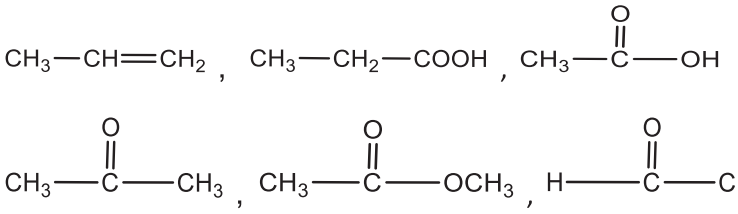
(iv) What is the difference between an alkane and an alkyl radical?

3. What do you mean by the term destructive distillation?

4. List some general properties of organic compounds.

5. List major commercial sources of alkanes.

6. Identify the following compounds on the basis of functional groups they contain and encircle the functional group.



7. What is the name of alkane having seven carbon atoms in the chain?

8. What is the name of the alkyl group obtained by removing an end hydrogen atom from (i) propane (ii) ethane?

9. Give the structural formula of two simple alkanes and one alkyne.

10. What is meant by the term functional group?

11. Identify the type of following compounds as an alcohol, aldehyde or ketone:

(a) HCHO, which is used to manufacture polymers, such as urotropine which is used to treat urinary tract infection.

(b) CH_3COCH_3, which is used in nail polish remover.

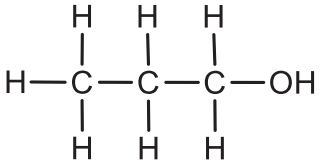
(c) CH_3CH_2OH, which is used in the preparation of many organic substances such as plastics, cosmetics, tinctures etc.

Think-Tank

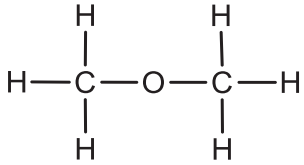
11. Give molecular formula of a compound containing C, H and O and single bonds. List all the possible functional groups this compound can have?

12. Give the condensed structural formulas of the following compounds and classify each on the basis of functional group.

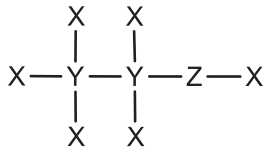
(a)



(b)



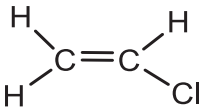
13. The diagram represents an organic compound that contains three different elements.



Select the possible compound from the following.

a) Ethanoic acid b) Propene c) Ehanol d) Propane.

15. Polyvinyl chloride (PVC) is a polymer. It is used for making vinyl sheets, drainage pipes, wire insulation etc. It is obtained from vinyl chloride

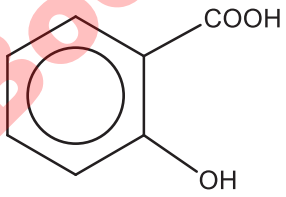


Classify Vinyl chloride as saturated or unsaturated compound.

16. For each of the following, sketch the structural formulas of a two–carbon compound containing the indicated functional group.

(a) alcohol (b) aldehyde (c)carboxylic acid (d) alkene

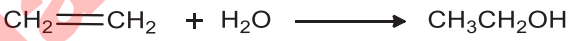
17. Aspirin is a mild pain killer and fever reducer. It is manufactured from salicylic acid.



Select functional groups present in it and encircle them. Justify your selection.

18. General formula for alkane is C_nH_{2n+2}. Construct the general formula for alkyl radical?

19. Water adds to ethene according to the following reaction



Compare the functional groups in the reactant and product molecules.

20. Bonding of carbon atom to heteroatoms increases the number of organic compounds. Justify it.

12

HYDROCARBONS

After completing this lesson, you will be able to:

This is 10 days lesson (period including homework)

- Explain why systematic method of naming chemical compounds is necessary.
- Characterize a hydrocarbon.
- Draw electron cross and dot structures of simple alkanes.
- Write a chemical equation to show the preparation of alkanes from hydrogenation of alkenes and alkynes and from reduction of alkyl halides.
- Draw structural formulas of alkanes, alkenes and alkynes up to 5 carbon atoms.
- Write a chemical equation to show the preparation of alkenes from dehydration of alcohols and dehydrohalogenation of alkyl halides.
- Write a chemical equation to show the preparation of alkynes from dehydrohalogenation of 1, 2- dihalides and dehalogenation of tetrahalides.
- Write chemical equations showing halogenation of alkanes, alkenes and alkynes.
- Write chemical equations showing reaction of $KMnO_4$ with, alkenes and alkynes.
- Determine the boiling point of alcohol.
- Explain hydrocarbons as fuel.
- Explain hydrocarbons as feed stock in industry.

Reading

INTRODUCTION

The simplest organic compounds are hydrocarbons. **The organic compounds which contain only two elements, carbon and hydrogen are called hydrocarbons.** There are several kinds of hydrocarbons. They are classified according to the type of bonding between the carbon atoms. You have learnt differences between alkanes, alkenes and alkynes in the previous chapter.

About 90% of the energy used to sustain our way of life comes from **fossil fuels.** Coal, natural gas and petroleum are called **fossil fuels**. Why are these

fuels called as fossil fuels? Natural gas is a mixture of low molecular weight hydrocarbons. Mainly it contains methane. Petroleum is a liquid mixture of mainly hydrocarbons. When these fuels are burnt, they produce carbon dioxide, water and heat. It has been estimated that the concentration of carbon dioxide in the atmosphere has increased up to 20% by the end of twentieth century. Carbon dioxide and other gases produce **greenhouse effect** (section 14.3.1).

Do you know?

Carbon dioxide and other gases in the air let the sun rays in, to warm the surface of earth. When the earth tries to radiate this heat back into the space, molecules of these gases trap this energy

About 25 billion tons of carbon dioxide is released into the atmosphere each year, 22 billion tons of it comes from the burning of fossil fuels. About 15 billion tons per year is removed by the plants. Thus 10 billion tons of carbon dioxide remains in the air. This is causing global warming. (For detail see section 14.3.1)

Although hydrocarbons burn, many of them are not generally used as fuel. They are mostly used as feed stock in industry. These hydrocarbons are starting raw materials for the synthesis of large number of organic compounds. These compounds have commercial importance.

Society, Technology and Science

Alkenes are starting materials for the synthesis of many valuable materials, especially polymers. Some alkenes and alkynes serve as starting materials for synthesis. For instance ethene and ethyne are used to synthesize a number of polymers. Polymers are made from smaller molecules such as ethene. Look around you, you will find polymers everywhere. Your clothes, carpets, curtains, towels, sheets, floor tiles, furniture, toys etc. are polymers made from ethene and ethyne. Even in your car, the dash board, seats, tyres, floor mat, ceiling, are also made of polymers. Hydrocarbons are also used as raw materials for the synthesis of synthetic rubber, plastic, films, adhesives, drugs and dyes. In the field of medicine, body replacement parts are made from polymers. In future we will have artificial bones that can stimulate bone growth. We can also expect to have artificial lungs as well as artificial hearts. Industries are day and night busy in synthesizing marvelous new products. Is there anything that can replace petroleum as raw material for making plastics and other polymers?

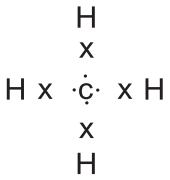
Millions of organic compounds exist. To understand, recognize and classify these compounds, systematic naming of organic compounds is necessary. Organic chemists began in the last century to devise a system of naming organic compounds that depends on their structure. An international body, **the International Union of Pure and Applied chemistry (IUPAC, pronounced "eye-you-pac")** constantly reviews the rules for naming organic compounds. IUPAC system of naming organic compounds is based on the following principle.

Each different organic compound should have a different name.

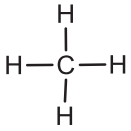
12.1 ALKANES

Alkanes are saturated hydrocarbons. They have general formula C_nH_{2n+2}.Each carbon atom forms four bonds and each hydrogen atom forms only one bond. So the simplest alkane

molecule that is possible is CH_4. It is called methane. Methane is the main component of natural gas. Electron dot and cross structure for methane is as follows.

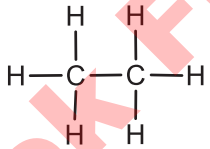


So the structural formula for methane is



Recall that structural formula shows which atoms are bonded to each other. The next member of alkane series is ethane, C_2H_6.

Ethane molecules has following structure



Example 12.1: Writing structural formula for an alkane.

Write structural formula for propane.

Problem Solving Strategy

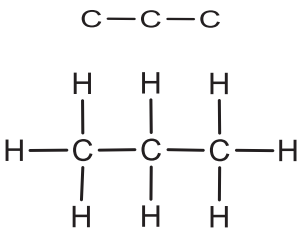
(i) Prop-means three carbon atoms.

(ii) Ending –ane indicates an alkane.

(iii) Write a string of three carbon atoms.

(iv) Attach hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

Solution



Self-Assessment Exercise 12.1

Write structural formulas for **(a)** Butane **(b)** Pentane

Example 12.2: Writing electron dot and cross structure for alkanes.

Draw the electron dot and cross structure for ethane.

Do you know?

Many halogenated hydrocarbons have important commercial uses. Methyl chloride is a gas at room temperature. Dichloromethane, trichloromethane and tetra chloromethane are liquids. These three liquids can be used as solvents for grease, oils and other organic substances. Chloroform is used as an anesthetic. Tetrachloromethane has carcinogenic effects at high concentration.

Problem Solving Strategy

(i) Write carbon atoms in a row.

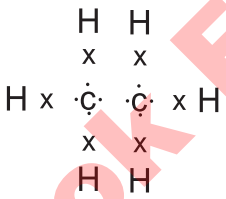
(ii) Show four elections by dots around each carbon atom.

(iii) Arrange hydrogen atoms around carbon atoms so that each carbon is surrounded by four atoms.

(iv) Show valence electrons of hydrogen by cross.

(v) Connect atoms by electron pairs

Solution



Self-Assessment Exercise 12.2

Draw electron dot and cross structures for the following.

(a) Propane **(b)** Butane

Reading

12.1.1. General Methods of Preparations of Alkanes

1. By Hydrogenation of alkenes and alkynes

Addition of hydrogen molecule across carbon-carbon multiple-bond is called hydrogenation. Hydrogenation takes place in presence of finally divided nickel at 200 – 300° C and high pressure. Hydrogenation can also be done in presence of Pt or Pd at room temperature.

Alkynes add two molecules of hydrogen. Why?

$$\underset{\text{Ethyne}}{CH \equiv CH} + H_2 \xrightarrow{Ni,200-300^oC} \underset{\text{Ethene}}{CH_2 = CH_2}$$

$$CH_2 = CH_2 + H_2 \xrightarrow{Ni,200-300^oC} CH_3 - CH_3$$

Ethene — Ethane

Self-Assessment Exercise 12.3

Complete the following reactions

$$CH_3 - CH = CH_2 + H_2 \xrightarrow{Ni,200-300^oC}$$

$$CH_3 - C \equiv CH + 2H_2 \xrightarrow{Ni,200-300^oC}$$

Reading

2. By the reduction of alkyl halides

When an alkyl halide is treated with Zn in presence of an aqueous acid, an alkane is produced. Usually aqueous solution of HCl or CH_3COOH is used.

$$CH_3 - Cl + 2[H] \xrightarrow{Zn/HCl_{(aq)}} CH_4 + HCl$$

Zn reacts with aqueous acid to liberate atomic hydrogen called nascent hydrogen. Nascent hydrogen reduces alkyl halide. Addition of nascent hydrogen is called reduction.

Self-Assessment Exercise 12.4

Complete the following reactions.

(a) $CH_3-\underset{\displaystyle Cl}{\underset{|}{CH_2}} + [H] \xrightarrow[HCl_{(aq)}]{Zn}$

(b) $CH_3-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_3 + 2|H| \xrightarrow[H_2SO_{4(\,aq)}]{Zn}$

Reading

12.1.2. Properties of Alkanes

Alkane molecules are essentially non-polar. They are less dense than water and are insoluble in it. Chemically alkanes are unreactive towards most ionic compounds. This lack of

reactivity makes them useful solvents. For instance hexane is used to extract vegetable oils from Corn, Soya beans, Cotton seed etc.

Alkanes containing upto four carbon atoms are colourless, odourless gases. Alkanes containing five to seventeen atoms are colourless, odourless liquids. Higher alkanes are solids which are also colourless and odourless.

1. Halogenation

Although unreactive towards ionic substances, alkanes readily react with halogens in sunlight. The reaction of an alkane and a halogen is a **substitution reaction.** In this reaction a halogen atom substitutes for one or more of the hydrogen atoms of an alkane.

For examples the reaction of methane and chlorine in diffused sunlight occurs as follows.

$$CH_{4(g)} + Cl_{2(g)} \xrightarrow{diffusedsunlight} CH_3Cl_{(g)} + HCl_{(g)}$$

Chloromethane

$$CH_3Cl_{(g)} + Cl_{2(g)} \xrightarrow{diffusedsunlight} CH_2Cl_{2(g)} + HCl_{(g)}$$

Dichloromethane

$$CH_2Cl_{2(g)} + Cl_{2(g)} \xrightarrow{diffusedsunlight} CHCl_{3(g)} + HCl_{(g)}$$

Trichloromethane

(Chloroform)

$$CHCl_{3(g)} + Cl_{2(g)} \xrightarrow{diffusedsunlight} CCl_{4(g)} + HCl_{(g)}$$

Tetrachloromathene

(carbon tetrachloride)

In direct sunlight the reaction of methane with chlorine is explosive and forms carbon and HCl.

$$CH_{4(g)} + 2Cl_{2(g)} \xrightarrow{directsunlight} C_{(s)} + 4HCl_{(g)}$$

The chlorination of methane usually produces a mixture of products. The trend in reactivity of halogen with an alkane is as follows

$$\boldsymbol{F_2 > Cl_2 > Br_2 > I_2}$$

Fluorine reacts explosively; chlorine reacts slowly in dark at room temperature but rapidly in strong sunlight. Bromine is less reactive than chlorine and requires high temperature or strong sun light. Iodine is essentially unreactive.

2. Combustion

A reaction of a substance with oxygen or air that causes the rapid release of heat and the appearance of a flame is called combustion. Complete combustion of an alkane produces carbondioxide, water and heat. Most of alkanes burn with blue flame.

For example, following reaction occurs when natural gas is burned.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)} + heat$$

The lighter alkanes are widely used as fuel. This is because:

(i) Their combustion can be controlled.

(ii) They produce large amount of heat per gram.

(iii) They are cheap and readily available.

Incomplete combustion occurs in presence of limited supply of oxygen. Incomplete combustion of methane gives CO, C and H_2O.

$$3CH_{4(g)} + 4O_{2(g)} \longrightarrow 2CO_{(g)} + C_{(s)} + 6H_2O_{(g)}$$

Uses of methane

Methane is used

(i) as domestic fuel (Sui gas).

(ii) as a fuel for automobiles (CNG).

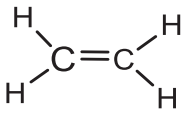
(iii) to manufacture urea fertilizer.

12.2. ALKENES

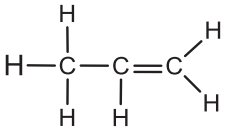
Alkenes have one or more double bond between carbon atoms. They have the general formula C_nH_{2n}. When two carbon atoms share two pairs of electrons, they form a double bond between the carbon atoms. How many electrons are left on each carbon atoms? Doubly bonded carbon atoms form single bond with two other atoms.

Do you know?

Ethylene or ethene is the most important commercial organic chemical. It is used in the manufacturing of polythene, one of the most familiar plastics. It is also converted to ethylene glycol which is used as antifreeze in auto mobile radiators.



Ethene



Propene

Example12.3: Writing structural formulas for alkenes.

Draw structural formulas for

(a) 1- Butene

(b) 2- Butene

Problem Solving Strategy

(i) But- means four carbon atoms.

(ii) Ending – ene indicates and alkene.

(iii) Write a string of four carbon atom and assign number to each carbon atom from one side.

Teacher's Point

Teacher may give example of blackening of cooking pots for in complete combustion of CH 4.

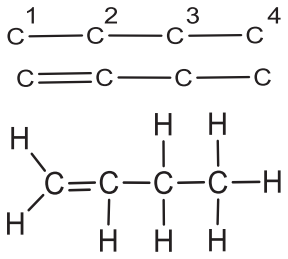
(iv) Number written before the name indicates the position of double bond. Make a double bond between indicated carbon-atom and the atom next to it.

(v) Attach enough hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

Solution

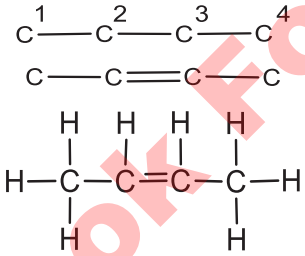
(a) 1 – Butane

Indicates double bond between C^1 and C^2



(b) 2 - Butene

Indicates double between C^2 and C^3



Self-Assessment Exercise 12.5

Draw structural formulas for the following compounds.

(a) 1 - Pentene **(b)** 2 – Pentene

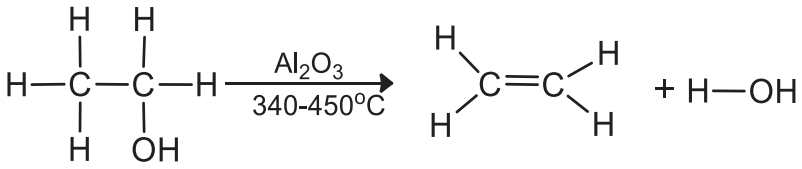
Reading

12.2.1. General Methods of Preparation of Alkenes

Alkenes are prepared by the following methods.

1. By Dehydration of Alcohols

Dehydration means loss of water. Alcohols dehydrate when their vapour are passed over heated alumina.



Ethanol Ethene

Phosphoric acid (H_3PO_4) and phosphorus pentaoxide (P_4O_{10}) can also be used as catalyst for dehydration of alcohols.

Concentrated sulphuric acid is also used for dehydration.

$$CH_3-\underset{\underset{OH}{|}}{CH_2} \xrightarrow[140\text{-}170^oC]{\text{Conc. } H_2SO_4} H_2C=CH_2 + H_2O$$

Note that in dehydration reaction -OH group is removed from one carbon and H atom from the adjacent carbon atom. Two such carbon atoms form double bond. Such a reaction is called elimination reaction.

Which alkene is formed by the dehydration of following alcohol?

$$CH_3-CH_2-\underset{\underset{OH}{|}}{CH_2}$$

2. Bydehydrohalogenation of alkyl halides

Dehydrohalogenation means loss of hydrogen halide. Alkyl halides on heating with alcoholic potassium hydroxide undergo dehydrohalogenation.

$$CH_3-\underset{\underset{Cl}{|}}{CH_2} + KOH \xrightarrow{\text{Alcohol}} CH_2=CH_2 + KCl + H_2O$$

Note that removal of H and halogen takes place from two adjacent carbon atoms. Is dehydrohalogenation an elimination reaction?

Self-Assessment Exercise 12.6

Complete the following reactions.

1. $CH_3-\underset{\underset{OH}{|}}{CH_2}-CH_2 \xrightarrow[170^oC]{\text{Conc. } H_2SO_4}$

2. $CH_3-\underset{\underset{Br}{|}}{CH_2}-CH_2 + KOH \xrightarrow{\text{Alcohol}}$

Science titbits

Alkenes occur widely in nature. Ripening fruits and vegetables give off ethene which helps in further ripening. So artificially ethene is used to hasten the normal ripening process. For example 1 kg of tomatoes can be ripened by exposure to 0.1mg of ethene for 24 hours. The red color of tomatoes is due to an alkene called Lycopene.

Reading

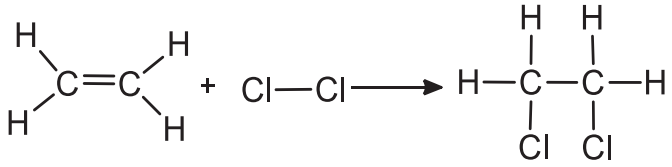
12.2.2 Properties of Alkenes

Alkenes are unsaturated hydrocarbons. First three members i.e. ethene, propene and butene are gases while C_5-C_{15} members are liquids and the higher members are solids. They are insoluble in water but soluble in organic solvents such as alcohol etc. The two carbons atoms

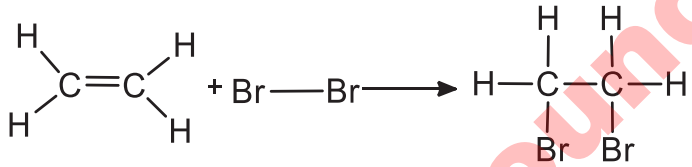
forming double bond are joined to only three atoms. Since a carbon atom can join to four atoms. So other molecules can attack at this site of double bond.

Reaction with halogens

Chlorine and bromine add to the double bond. One chlorine atom becomes attached with one carbon and the one with other carbon atom.



Such a type of reaction is called addition reaction. Alkenes react with bromine water in the same way.

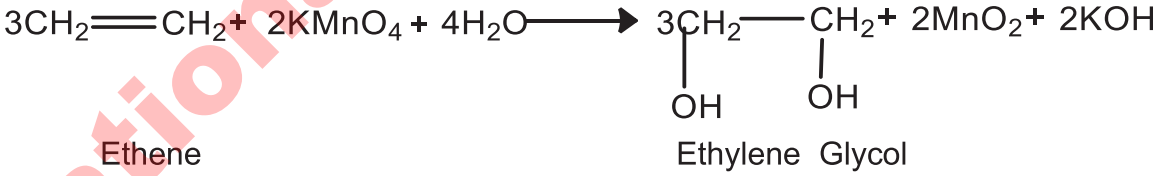


Ethene (colourless) (Reddish-brown) 1,2-Dibrome ethane (colourless)

Bromine is a reddish-brown liquid and the product is colourless. When bromine water is added to an alkene, the red-brown color disappears. The decolourization of bromine solution is frequently used as a simple test for the presence of unsaturation. Alkynes also give this reaction. (See section 12.3.2)

Reaction with $KMnO_4$

When an alkene is treated with dilute alkaline aqueous solution of $KMnO_4$ (1%) addition of two hydroxyl groups occurs across the double bond. The pink colour of $KMnO_4$ solution is discharged during the reaction. This reaction is used as a test for the presence of an alkene and is known as Baeyer's test.



Ethene Ethylene Glycol

Ethylene glycol is used as an anti-freeze.

Self-Assessment Exercise 12.7

Complete the following reactions

1. $CH_3 - CH = CH_2 + Br_2 \longrightarrow$
2. $CH_3 - CH = CH_2 + KMnO_4 + H_2O \longrightarrow$
3. $CH_3 - CH = CH_2 + Cl_2 \longrightarrow$

Reading

12. 3. ALKYNES

Do you know?
Acetylene is used in oxy-acetylene torches for cutting and welding metals. Such torches can produce temperature as high as 3000° C.

Hydrocarbons which have at least one triple bond between carbon atoms are called alkynes. Those with one triple bond have the general formula C_nH_{2n-2}.

Structure:

Ethyne, also called acetylene is the simplest member of alkyne family. In ethyne the two carbon atoms share three pairs of electrons. This means the carbon atoms are joined by a triple bond. How many hydrogen atoms can share electrons with each triply bonded carbon atoms? Structure of ethyne is

H – C ≡ C – H

Example 12.4: Writing structural formulas of alkynes

Draw structural formulas for

(a) 1-Butyne (b) 2-Butyne

Problem Solving Strategy

(i) But– means four carbon atoms.

(ii) Ending –yne indicates an alkyne.

(iii) Write a string of four carbon atoms and give number to each carbon atom form one side.

(iv) Number written before the names indicates the position of triple bond. Make a triple bond between this Carbon atom and next to it.

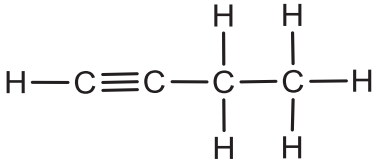
(v) Attach required number of hydrogen atoms to the carbon atoms to give each carbon atom four bonds.

Solution

(i)

$C^1—C^2—C^3—C^4$

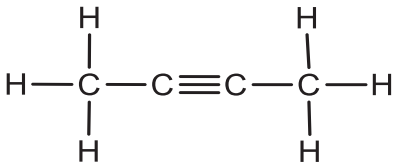
$C^1 \equiv C^2—C^3—C^4$



(ii)

$C^1—C^2—C^3—C^4$

$C^1—C^2 \equiv C^3—C^4$

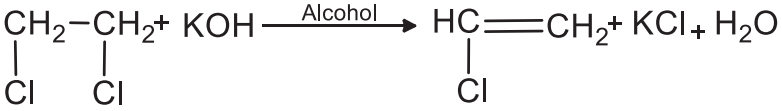


12.3.1. General Methods of Preparation of Alkynes

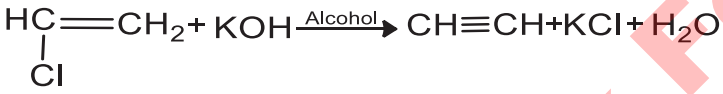
1. By Dehydrohalogenation of vicinal dihalides

A vicinal dihalide has two halogen atoms on adjacent carbon atoms. Which is vicinal dichloride?

Vicinal dihalide on treatment with alcoholic potassium hydroxide eliminates two molecules of hydrogen halides from adjacent carbon atoms. Removal of two molecules forms a triple bond between two carbon atoms. Reaction occurs in two steps.

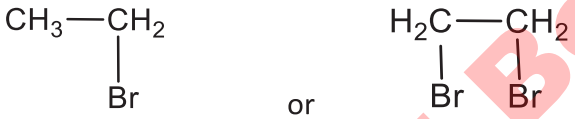


1,2Dichloroethane (Vicinal dihalide) Vinylchloride



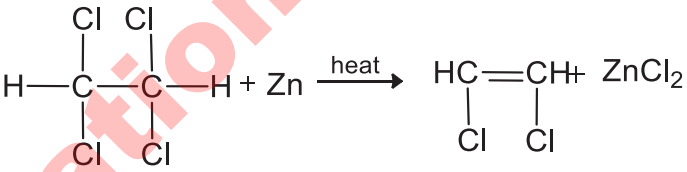
Ethyne

Which of the following alkyl halide will form alkyne on treatment with alcoholic KOH?

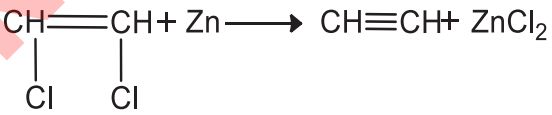


2. By Dehalogenation of Tetrahalides.

Tetra halides on treatment with Zn dust undergo dehalogenation forming an alkyne.



1, 1, 2, 2-Tetrachloroethane 1, 2-Dichloroethene



Ethyne

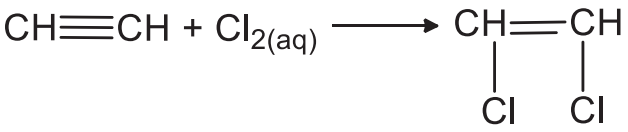
12.3.2. Properties of Alkynes

Like alkenes, alkynes are also unsaturated hydrocarbons. The first three members are gases, next eight members are liquids and higher members are solids. They are non-polar and dissolve readily in organic solvents. Ethyne has garlic like odour. Alkynes are reactive compounds due to presence of a triple bond. Alkynes undergo addition reaction across the triple bond.

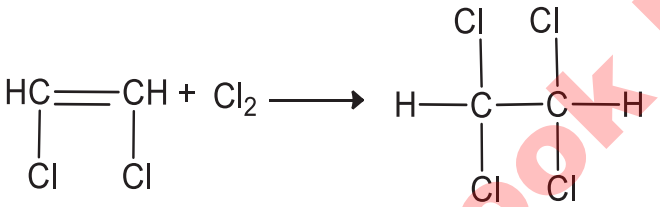
One molecule is added across the double bond in an addition reaction. Alkynes also undergo addition reactions like alkene. How many molecules will add across the triple bond?

1. Addition of Halogens

Alkynes add two molecules of halogens.



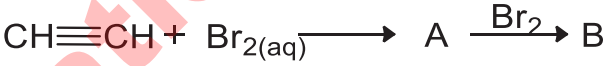
Ethyne 1,2 – Dichlorethene



Tetrachloroethane

Self-Assessment Exercise 12.8

Write chemical reaction of ethyne and bromine. Why this reaction is used to identify the unsaturation in a molecule?

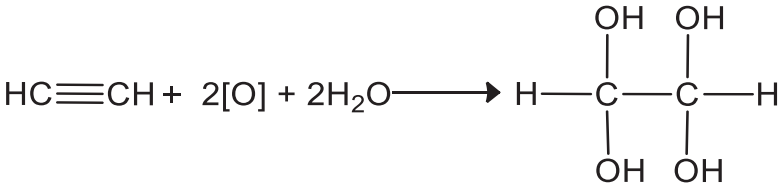


Reading

2. Reaction with $KMnO_4$

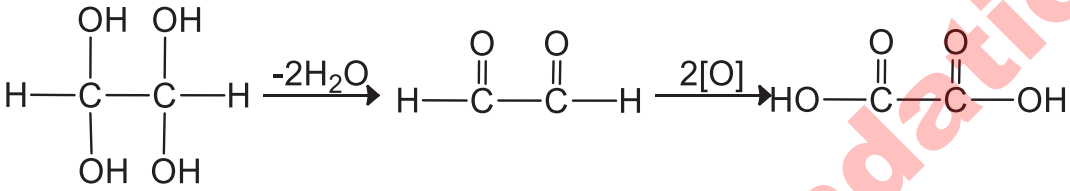
Alkynes do not react with dilute alkaline aqueous solution of $KMnO_4$. However, they are oxidized by strong alkaline solution of $KMnO_4$to give oxalic acid. First four hydroxyl groups are added across the triple bond.

$$4KMnO_4 + 4KOH \longrightarrow 4K_2MnO_4 + 4[O] + 2H_2O$$



Tetrahydroxy ethane

Tetrahydroxy ethane is unstable compound; it loses two water molecules to form glyoxal which finally oxidizes to oxalic acid.



Glyoxal Oxalic acid

Society, Technology and Science

Natural gas, petroleum and coal are important sources of hydrocarbons. These hydrocarbons are major source of energy. When they burn in air a highly exothermic reaction occurs. This reaction is called combustion reaction.

For example

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + heat$$

Hydrocarbons are used as fuel to meet our energy needs in homes, industries, motor vehicles and power generation.

Uses of Ethyne (Acetylene)

Ethyne is used:

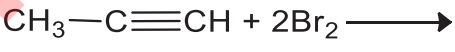
(i) In oxy-acetylene torch for welding and cutting metals.

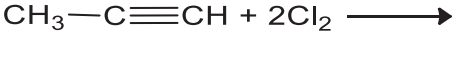
(ii) For ripening of fruits.

(iii) For the manufacture of polyvinyl acetate (PVA), polyvinyl chloride (PVC), polyvinyl ethers and rubber.

Self-Assessment Exercise 12.9

Complete the following reaction





SKILLS

Activity 12.1

Determining boiling point of alcohol

Perform this activity in the laboratory.

You will need:

- Bunsen burner, stand, wire gauze, stirrer, thread, fusion tube, capillary tube, beaker, thermometer and match box.
- An alcohol such as ethyl alcohol.

Carry out the following:

1. Place small amount of alcohol in the fusion tube and tie it to the thermometer with thread. The ends of fusion tube and thermometer should be equal.
2. Place a long capillary tube in the fusion tube.
3. Place the beaker containing water on the stand.
4. Suspend thermometer along with fusion tube in water. **(See figure 12.1)**
5. Heat the beaker and stir water with the stirrer.
6. Continue heating and stirring until bubbles start rising from the lower end of the capillary tube.
7. See the temperature on the thermometer when bubbles start to come from lower end of capillary tube. This is the boiling point of the liquid.

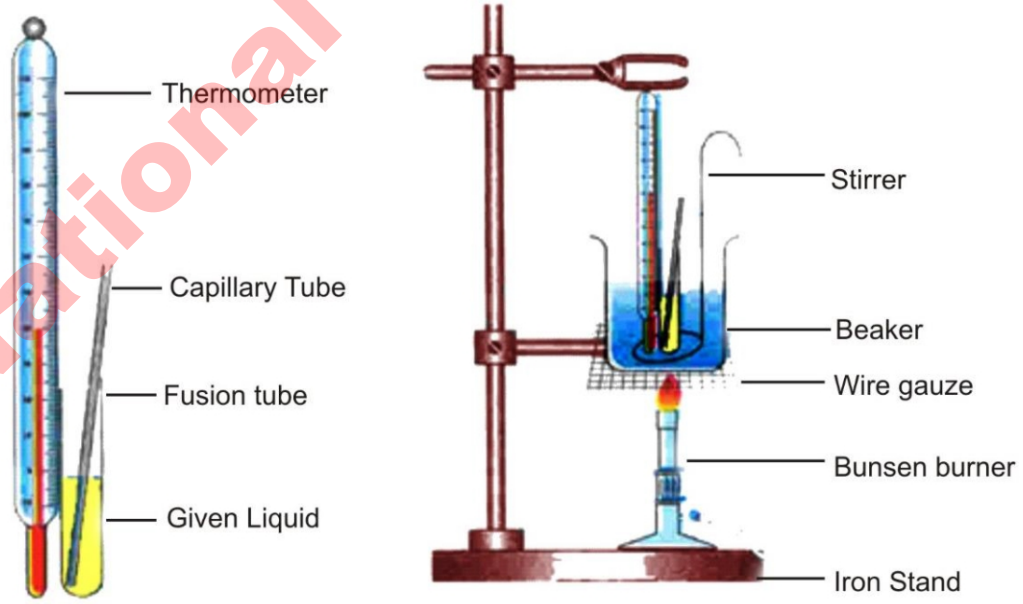
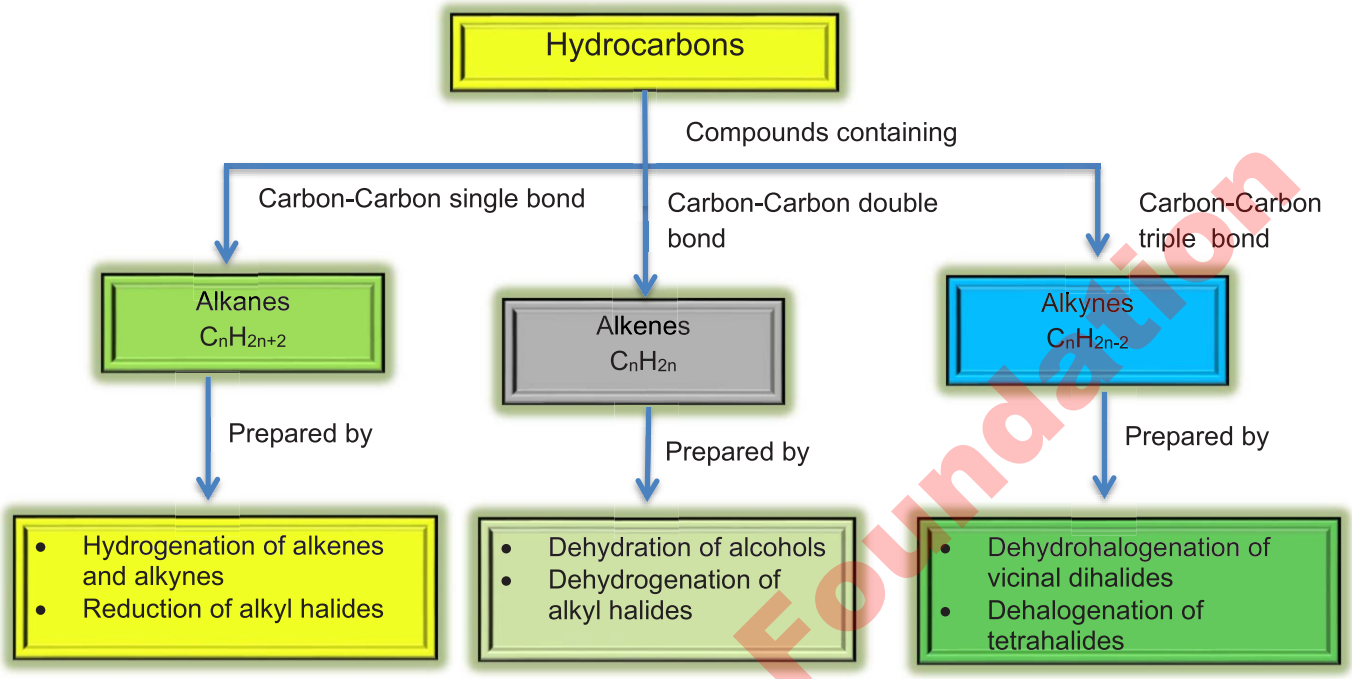


Figure 12.1: Determination of the boiling point of alcohol.

Concepts in brief



Key Points

- Hydrocarbons are compounds that contain carbon and hydrogen only.
- The simplest hydrocarbon that is possible is CH_4.
- Addition of hydrogen across carbon-carbon double or triple bond is called hydrogenation.
- Hydrocarbons that have at least one carbon-carbon double bond are called alkenes.
- Hydrocarbons that have at least one carbon-carbon triple bond are called alkynes.
- Dehydration is the loss of water.
- Removal of hydrogen halide is called as dehydrohalogenation.
- Alkenes and alkynes are unsaturated hydrocarbons.
- 1% alkaline aqueous solution of $KMnO_4$ is used to detect the presence of an alkene. The reaction is known as **Baeyer's test.**
- In alkynes the two carbon atoms share three pairs of electrons.
- A vicinal dihalide has two halogen atoms on adjacent carbon atoms.

References for additional informations.

- Longman chemistry for IGCSE.
- Chemistry, Addison, Wesley. Fifth Edition.

Review Questions

1. Encircle the correct answer

(i) Which molecule contains a carbon-carbon double bond?

(a) Ethane (b) Ethene (c) Ethyne (d) Ethyl alcohol

(ii) Which product is obtained when chloromethane (or methyl chloride) is reduced?

(a) Ethane (b) Ethene (c) Methane (d) Ethyne

(iii) Which reacts explosively with methane?

(a) F_2 (b) Cl_2 (c) Br_2 (d) I_2

(iv) By dehydration we mean, the removal of

(a) Hydrogen (b) Water (c) Halogen (d) Hydrogen halide

(v) Ethene and ethyne can be differentiated by

(a) Hydrogenation (b) Bromine water

(c) Strong alkaline aqueous solution of $KMnO_4$ (d) Hydrohalogenation

(vi) Which is used for dehydrohalogenation?

(a) Br_2 water (b) Conc. H_2SO_4 (c) Al_2O_3 (d) Alcoholic KOH

(vii) Which substance reacts with $KMnO_4$ to produced oxalic acid?

(a) Ethane (b) Ethene (c) Ethyne (d) Ethyl alcohol

(viii) The reduction of alkyl halides takes place in the presence of

(a) Al_2O_3 at 350°C (b) Conc. H_2SO_4 at 170°C

(c) Zn + Dust (d) Zn + HCl

(ix) Which process produces an alkane?

(a) Combustion (b) Hydration (c) Dehydration (d) Hydrogenation

(x) Does not react with aqueous solution of bromine

(a) C_2H_6 (b) C_2H_4 (c) C_2H_2 (d) C_3H_6

2. Give short answers.

(i) Give three examples of unsaturated hydrocarbons.

(ii) Draw electron dot and cross structure for ethene.

(iii) Draw structural formulas of an alkane, an alkene and an alkyne containing five carbon atoms.

(iv) How can you differentiate ethane from ethene?

(v) What do you mean by dehydration reaction? Give one example

3. How can you convert

(i) ethene into ethane (ii) methane into carbontetrachloride

(iii) ethene into glycol (iv) ethyl chloride into ethane

(v) ethyl bromide into ethene

4. Write a chemical equation to show the preparation of an alkane from an alkene and an alkyne.
5. Write a chemical equation to show the preparation of ethene from dehydration of an alcohol and dehydrohalogenation of alkyl halides.
6. Write a chemical equation to show the preparation of ethyne from dehalogenation of 1,2 -dihalide and a tetrahalide.
7. Write chemical equations showing reaction of $KMnO_4$ with ethene and ethyne.
8. List some industrial uses of ethene and ethyne.
9. Explain why a systematic method of naming chemical compounds is necessary.
10. Draw electron dot and cross structure for

(a) Propane (b) Propyne (c) Propene

Think-Tank

11. Write chemical equations for the preparation of propene from

(a) $CH_3-CH_2-CH_2-OH$ (b) $CH_3-C \equiv CH$

12. Write down structural formulas for the products which are formed when 1-butene is reacted with

(a) H_2 /Ni (b) dilute alkaline aqueous $KMnO_4$ solution

(c) bromine water (d) chlorine

13. Identify A, B, C, D in the following reactions.

(i) $Propene \xrightarrow{Br_2} A \xrightarrow{alcoholKOH} B$

(ii) $Ethylalcohol \xrightarrow{Conc.H_2SO_4} C \xrightarrow{Br_2} D$

14. Construct a scheme to convert ethene into ethyne?
15. You are given two flammable liquid hydrocarbons. One of them is an alkene and the other is an alkane. Design an experiment to find out which is which.
16. How many possible products are there when chlorine reacts with ethane? Sketch them all.
17. Differentiate between ethene and ethyne.

About Authors

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She obtained her Master' degree in Chemistry from Quaid-i-Azam University, Islamabad, and has over twenty eight years of teaching experience. She is serving in Islamabad Model College for Girls, F-10/2 Islamabad.

Along with teaching, she has been contributing lot extensively to the promotion of Chemistry. She has translated Textbook of Chemistry from English to Urdu for class XI, for the National Language Authority. She has also co-authored the Textbook of Chemistry for class XII for Allama Iqbal Open University, Islamabad. Besides this she has been involved in writing, editing, and comparing Television programs of Chemistry for Secondary classes.

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In 1980, he launched himself into the teaching profession, when he joined the Chemistry Department of Army Burn Hall College Abbottabad. In 1982, he joined the Islamabad College for Boys, G-6/3, Islamabad and also served as Principal in various colleges in Islamabad. He retired as Principal from Islamabad College for Boys (ICB) G-6/3, Islamabad. On the occasion of the Silver Jubilee celebrations of I.C.B, G-6/3 he was declared as the best teacher in Chemistry and awarded a gold medal.

His rich experience in teaching Chemistry, has enabled him to serve as member, National Review Committee from 2002-2006 for finalizing textbook manuscripts in the subject of Chemistry for Secondary and Higher Secondary classes, developed by various Textbook Boards. He is also Managing / Co-Author of several textbooks, published by NBF. For queries about book in question, please contact at: prof.iqtedar@gmail.com.

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مرکزِ یقین شاد باد!

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